SVEUČILIŠTE U ZAGREBU
FAKULTET STROJARSTVA I BRODOGRADNJE

DIPLOMSKI RAD

Filip Aralica

Zagreb, 2015.

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Izjavljujem da sam ovaj rad izradio samostalno koristeći stečena znanja tijekom studija i navedenu literaturu.

Prvenstveno bih se zahvalio roditeljima, Tomislavu i Vesni, na strpljenju bez granica. Bez vas ne bih bio tu gdje jesam. Također hvala mojoj braći i sestri, djedovima i baki te svoj ostaloj obitelji i prijateljima. Kolegicama i kolegama, profesoricama i profesorima, hvala na potpori i trudu. Hvala i docentu Vedranu Slapničaru, na velikodušnoj pomoći pri izradi rada.

I naravno Sanji, hvala što dijeliš ovaj trenutak sa mnom.

Filip Aralica

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DIPLOMSKI ZADATAK

Student: **Filip Aralica** Mat. br.: 0035161936

Naslov rada na hrvatskom jeziku: **ANALIZA STABILITETA I OPTEREĆENJA BRODA ZA PRIJEVOZ AUTOMOBILA I KAMIONA U OŠTEĆENOM STANJU**

Naslov rada na engleskom jeziku: **ANALYSIS OF STABILITY AND LOADS OF THE CAR-TRUCK CARRIER IN DAMAGED CONDITION**

Opis zadatka:

1. Proučiti pravila primjenjiva na stabilitet broda za prijevoz automobila i kamiona u oštećenom stanju kao i kriterije operativnosti ovih plovila.
2. U prikladnom programskom paketu izraditi model broda za proračun stabiliteta oštećenog broda.
3. Odrediti standardna i nestandardna stanja krcanja potrebna za proračun.
4. Odrediti standardne i nestandardne slučajeve oštećenja.
5. Izraditi matricu koja će opisivati lokacije i dimenzije oštećenja, stabilitet u oštećenom stanju te vertikalne sile i momente za ova oštećenja.
6. Ispitati razlike u rezultatima dobivenim vjerojatnosnom metodom i standardom oštećivanjem dva susjedna tanka.
7. Napraviti algoritam kojim će se opisati cijeli postupak.

Literatura: Dokumentacija postojećeg broda

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Oznaka	Jedinica	Opis
L_{oa}	m	Dužina preko svega (eng.: Length Overall), najveća duljina trupa broda mjerena paralelno sa vodnom linijom
L_{pp}	m	Dužina među okomicama (eng.: Length between Perpendiculars), duljina broda od krmene okomice do pramčane okomice
L_S	m	Pregradna dužina broda, najveća pregradna dužina broda na ili ispod palube koja ograničava vertikalnu naplavu dok je brod na najdubljem pregradnom gazu d_S
B	m	Širina broda (eng.: Beam), najveća širina trupa
T	m	Gaz broda (eng.: Draft), okomita udaljenost od osnovice ili ruba kobilice do vodne linije broda
D	m	Visina broda (eng.: Depth), visina od kobilice do donjeg ruba posljednje neprekinute palube
D_{GP}	m	Visina do glavne palube, visina od kobilice do donjeg ruba palube čvrstoće
Δ	m	Istisnina (eng.: Displacement), masa morske vode ekvivalentna volumenu uronjenog dijela trupa
DWT	t	Nosivost (eng.: Deadweight), masa koju nosi brod (ne uključuje masu lakog broda)
N_{MAX}		Najveći broj automobila koje može prevoziti karakterističan brod
v_{pp}	čv	Brzina na pokusnoj plovidbi
C_B		Koeficijent punoće (eng.: Block coefficient), pokazuje omjer volumena uronjenog dijela trupa broda naspram volumena fiktivnog kvadra čije su stranice gabariti uronjenog dijela trupa broda
LCG	m	Položaj težišta mase po duljini (eng.: Longitudinal Centre of Gravity)
VCG	m	Položaj težišta mase po visini (eng.: Vertical Centre of Gravity)
GM	m	Metacentarska visina
Area	m rad	Površina ispod krivulje poluga stabiliteta
ra	m	Poluga stabiliteta (eng.: Righting Arm)
raø	deg	Točka iščezavanja stabiliteta (eng.: Righting Arm Vanishing Point), kad bočni nagib broda dosegne vrijednost *raø* brod se više ne može vratiti u početno stanje te dolazi do prevrtanja
f ili *FWD*		Oznaka za smjer prema pramcu (eng.: foreward; fore)
a ili *AFT*		Oznaka za smjer prema krmi (eng.: aft)
FP		Pramčana okomica
AP		Krmena okomica
R		Zahtijevani indeks pregrađivanja (eng.: Required subdivision index)

A		Dostignuti indeks pregrađivanja (eng.: Attained subdivision index)
p		Faktor vjerojatnosti naplavljivanja odjeljka u slučaju oštećenja
v_m		Faktor redukcije vjerojatnosti naplavljivanja prostora iznad promatranog odjeljka
s_i		Faktor vjerojatnosti preživljavanja broda u slučaju oštećenja odjeljka
l_c	m	Uzdužna duljina oštećenja boka
L_{LL}	m	Dužina vodne linije, na 85% najmanje visine *D* od vrha kobilice, mjerena od pramca do osi struka kormila, ne manja od 96% L_{oa} na toj vodnoj liniji
l_s	m	Uzdužna duljina oštećenja dna
t_c	m	Poprečna duljina oštećenja boka
t_s	m	Poprečna duljina oštećenja dna
v_c	m	Vertikalna duljina oštećenja boka
v_s	m	Vertikalna duljina oštećenja dna
d_S		Najdublji pregradni gaz, vodna linija koja odgovara ljetnoj vodnoj liniji broda.
d_P		Djelomični pregradni gaz, iznosi 60% razlike između gaza pri lakoj eksploataciji i najdubljeg pregradnog gaza.
d_L		Gaz pri lakoj eksploataciji, gaz u eksploataciji koji odgovara najmanjem predviđenom stanju krcanja sa uračunatom dovoljnom količinom balasta za stabilitet i minimalni gaz.
GZ	m	Poluga statičkog stabiliteta
CG	m	Oznaka za težište (eng.: Centre of Gravity)
TCG	m	Položaj težišta mase po širini
SpGr	kgm^{-3}	Gustoća (eng.: Specific Gravity)
FSM	t m	Moment slobodne površine
LCB	m	Položaj težišta istisnine po duljini
TCB	m	Položaj težišta istisnine po širini
VCB	m	Položaj težišta istisnine po visini
LCP	m	Položaj kritične točke po duljini
TCP	m	Položaj kritične točke po širini
VCP	m	Položaj kritične točke po visini
GML	m	Oznaka za poprečnu metacentarsku visinu u programu GHS
GMT	m	Uzdužna metacentarska visina
μ		Naplavljivost, omjer volumena prostora koji može biti naplavljen vodom naspram ukupnog volumena prostora.

SAŽETAK

Povećanjem globalne povezanosti i trgovine povećava se i promet prijevoza tereta brodovima. Bili to tankeri, kontejnerski brodovi, razni brodovi za dostavu, plutajuće rafinerije itd... ili brodovi za prijevoz tereta na kotačima. Radi povećanog prometa brodova, za očekivati je da će se sve veći značaj pridodavati sigurnosti posade, broda i tereta.

U ovom radu je modeliran brod za prijevoz tereta na kotačima, te je koristeći program GHS izvršen proračun stabiliteta oštećenog broda vjerojatnosnom metodom. Također je za isti model izvršen proračun stabiliteta u oštećenom stanju determinističkom metodom oštećivanja, prvo jednog po jednog tanka, potom po dva susjedna i na kraju po tri susjedna tanka. Modelom su u vjerojatnosnom proračunu obuhvaćena tri stanja krcanja broda, kako je definirano u pravilima [9], dok je model u determinističkom proračunu definiran s dva početna stanja krcanja procijenjena kao granična. Svako od tih početnih stanja oštećeno je s 27 različitih slučajeva oštećenja. Rezultat vjerojatnosnog proračuna je indeks pregrađivanja *A*, dok je rezultat determinističkog proračuna predstavljen s prikazom oštećenih prostora i karakterističnih krivulja stabiliteta te uzdužne čvrstoće. Dobiveni rezultati uspoređeni su s propisima [9] i rezultatima za neoštećeno stanje. Pokazalo se da brod u svim stanjima oštećenja zadovoljava kriterije stabiliteta po determinističkoj metodi. Rezultati vjerojatnosne analize uspoređeni su s rezultatima izrađenim prema prethodnim pravilima [4] te je zaključak da je novi kriterij, donesen 2008. godine povećao zahtijevani indeks pregrađivanja *R*. Usprkos tome, dobiveni indeks *A* je veći od zahtijevanog indeksa *R*.

Ključne riječi: stabilitet broda u oštećenom stanju, vjerojatnosna metoda, deterministička metoda, ro-ro brod, brod za prijevoz tereta na kotačima, uzdužna čvrstoća, pomorske nesreće, IMO, SOLAS, Bureau Veritas, indeks pregrađivanja

SUMMARY

With the increase of global goods exchange and commerce, global marine traffic also attained new heights. Weather they are tanker, container, ro-ro, FPSO, shuttle or ro-ro ships. Increased traffic brought about a new and increased outlook on crew, ship and cargo safety. In line with this expectance in this master's course thesis a ro-ro ship model was made, and using the program GHS damage stability was calculated both using the deterministic method and the probabilistic method. The probabilistic approach analyses three load cases, each with a corresponding subdivision load line, as defined by IMO and classification societies [9]. The deterministic approach analyses two load cases which were deemed most critical, each of which was damaged with 27 different damage cases, some of which go beyond those required by classification societies. Results for the probabilistic method are in the form of attained subdivision index *A*, and the results of the deterministic method are characteristic stability curves and longitudinal strength curves, followed up with stability criteria compliance check. The deterministic method results are compared against intact ship values, and the probabilistic method results are compared to previous calculation values according to rules [4]. Results show that all criteria are satisfied both for the deterministic approach and the probabilistic approach.

Key words: ro-ro ship, damage stability, marine accidents, probabilistic method, deterministic method, longitudinal strength, IMO, SOLAS, Bureau Veritas, subdivision index, two compartment ship

1. UVOD

Kroz povijest gradnje brodova, stabilitet je bio jedno od glavnih svojstava po kojima se mjerila sigurnost broda. Postavljajući zahtjeve stabiliteta propisivane su granice sigurnosti za brodove, tj. minimalni stupanj sigurnosti za brod, ljude, teret i okolinu koji se nalaze na brodu ili oko njega. Jedan od mnogih elemenata koji određuju sigurnost je i stabilitet oštećenog broda. U početku su od strane meritornih tijela bili propisani prilično mali zahtjevi stabiliteta broda. Danas su zahtjevi veći, a postavljeni su od Međunarodne pomorske organizacije (International Maritime Organization – IMO) [1]. Brodovi moraju imati dovoljnu stabilnost u neoštećenom stanju te moraju biti pregrađeni što je moguće efikasnije imajući u vidu namjenu za koju su izgrađeni, u svrhu osiguravanja uzgona i stabiliteta nakon sudara ili oštećenja.

Prva pravila za oštećeni brod uvedena su kao posljedica konvencije SOLAS koja je održana 1914. god. nakon tragedije RMS "Titanic"-a. Potom su krenule revizije 1929. godine, 1948. godine, 1960. godine te 1974. godine. Ova posljednja je postala i ostala baza za sve buduće promjene, i poznatija je kao SOLAS '74. Princip donošenja novih pravila je u donošenju amandmana koji dolaze na snagu na zadani datum. Prije dolaska na snagu, zainteresirane strane moraju provjeriti i odobriti taj amandman. Kao rezultat takvog načina ažuriranja pravila, današnja verzija je i dalje SOLAS '74, s amandmanima. [1]

Prva pravila na osnovi vjerojatnosti za putničke brodove sadržana su u IMO rezoluciji A.265 , a uvedena su 1967. godine kao alternativa determinističkim pravilima SOLAS '60. Za većinu putničkih ro-ro brodova ova pravila su stroža od determinističkih zahtijeva sadržanih u SOLAS '60, te se uglavnom nisu primjenjivala kao obavezna. [2]

Sljedeći veliki korak u razvoju stabiliteta bio je 1992. godine uvođenjem IMO rezolucije MSC.19(58) [3] u SOLAS kao dio B-1 (u poglavlju II-1) koji sadržava standard stabiliteta za teretne brodove na vjerojatnosnoj osnovi preživljavanja broda nakon sudara. Referentna veličina je koeficijent pregrađivanja *A*.

Zahtjevi za pregrađivanje i stabilitet teretnih brodova u oštećenom stanju sadržani su u IMO Rezoluciji A.684(17) koja se odnosi na sve teretne brodove iznad 80 m, isključivši one brodove za koje se pokaže da osim pravila Međunarodne konvencije o sigurnosti na moru

1974. s dopunama, udovoljavaju drugim pravilima o pregrađivanju i stabilitetu u oštećenom stanju Međunarodne pomorske organizacije. [4]

2006. godine u rezoluciji MSC.216(82) [5] Međunarodna pomorska organizacija je prihvatila opsežan amandman na SOLAS poglavlje II-1. Odnosi se na zahtjeve za stabilitet broda u oštećenom stanju te duljinu pregrađivanja. Donesena je u svrhu harmoniziranja zahtjeva za putničke i teretne brodove. Rezolucija se odnosi na vjerojatnosnu metodu određivanja stabiliteta oštećenog broda. Cilj je ostao isti, "Brod mora biti podijeljen na najučinkovitiji način moguć, imajući obzira na njegovu namjenu. Opseg pregrađivanja će varirati s ukupnom duljinom pregrađivanja na takav način, da brodovi s najduljom duljinom pregrađivanja imaju najveći opseg pregrađivanja, s osobito povećanim opsegom ukoliko brod prevozi putnike."

2008. godine objavljena je rezolucija IMO MSC.281(85) - lista pojašnjenja (Explanatory notes) SOLAS poglavlju II-1, a odnose se na pregradnu dužinu i stabilitet u oštećenom stanju. Pomorski odbor za sigurnost (MSC - Maritime safety committee) je u rezoluciji predvidio nove dopune i pojašnjenja vjerojatnosnog pristupa stabilitetu oštećenog broda. Jedna od dopuna uključuje objašnjenje filozofije vjerojatnosnog pristupa, gdje se tvrdi: "Filozofija vjerojatnosnog koncepta je da su dva broda s istim postignutim indeksom pregrađivanja A jednako sigurna, i da stoga nema potrebe za dodanim zahtjevima ili specijalnim tretmanom određenih dijelova broda. Jedina područja koja su posebno razmatrana su pramac i dno. Oba imaju priložena posebna pravila pregrađivanja za slučajeve bočnog oštećenja i nasukavanja. (eng.: ramming i grounding)" [6]

Međunarodna pomorska organizacija, već duže vrijeme radi na harmonizaciji standarda za stabilitet. Stupanje na snagu pravila koji se primjenjuju i na postojeće brodove, jedna je od glavnih briga brodovlasnika. Ovo obično utječe na povećanje cijene, ali također može utjecati na kapacitet broda glede nosivosti, broja putnika, brzine, duljine ukrcajne trake, vremena potrebnog za prekrcaj i vremena potrebnog za pristajanje. Kako bi se ovo izbjeglo, te zadovoljilo i buduće zahtjeve za sigurnim brodovima, vlasnici zahtijevaju da novi brodovi budu građeni ne samo prema postojećim pravilima nego i prema novim mogućim zahtjevima koji će doći. Ovo predstavlja izazov za projektante u smislu predviđanja vjerojatnog izgleda novih pravila i određivanja rješenja povoljnih s obzirom na cijenu.

Uzevši u obzir rezoluciju MSC.281(85) i predviđanje novih poboljšanja i promjena pravila, za očekivati je da će područje stabiliteta oštećenog broda biti veoma aktualno u očima brodovlasnika i brodograditelja u budućnosti.

2. ODABIR PRIKLADNOG MODELA BRODA ZA PRORAČUN

Prije nego li je moguće započeti rad na proračunima, potrebno je kreirati i adekvatno uskladiti model broda za koji će se proračunavati stabilitet u oštećenom stanju. Model je odabran iz prethodno objavljenog diplomskog rada, za koji je dobivena projektna dokumentacija i adekvatni nacrti.

Odabran je brod za prijevoz automobila i kamiona [Slika 1. i Slika 2.] sa sljedećim glavnim značajkama:

Glavne značajke broda:

Tip broda: .... Car – truck carrier

Klasifikacijsko društvo: .... Registro Italiano Navale

Duljina preko svega: .... $L_{oa} = 176,00$ m

Duljina između okomica: .... $L_{pp} = 165,00$ m

Pregradna duljina L_s: .... $L_s = 171,43$ m

Širina: .... $B = 31,10$ m

Gaz: .... $T = 8,766$ m

Visina: .... $D = 28,00$ m

Visina do glavne palube: .... $D_{G.P.} = 14,46$ m

Istisnina: .... $\Delta = 24825$ t

Nosivost: .... $DWT = 12594$ t

Maksimalni broj osobnih vozila:............... $N_{MAX} = 4632$

Brzina: .... $v_{pp} = 20,10$ čv

Koeficijent punoće: .... $C_B = 0,514$

Glavni motor: .... Man B&W 7S50MC-C

Izlazna snaga: .... 11060 kW pri 127 o/min

Težište sustava broda po duljini: .... $LCG = 79,780$ m

Težište sustava broda po visini: .... $VCG = 14,337$ m

Slika 1. Karakteristični brod [7]

Slika 2. Pogled prema krmenoj rampi karakterističnog broda [7]

3. PROGRAMSKI PAKET GENERAL HYDROSTATICS

Kako bi se započeo rad na proračunima stabiliteta broda u oštećenom stanju, potrebno je pripremiti model na takav način kako to zahtjeva program GHS.

3.1. Programski paket General Hydrostatics

Programski paket General Hydrostatics sastoji se od glavnog programa, nazvanog GHS i nekoliko pomoćnih programa. Pomoćni programi su izdvojeni iz glavnog programa zbog razvoja istih. Svi dijelovi GHS programskog sučelja, bez obzira na pomoćni program u kojem su izvedeni, su dostupni u glavnom programu. Programski alati GHS-a mogu se podijeliti na dvije skupine:

- programski alati za izradu modela broda
- programski alati za obradu modela broda

Programski alati za izradu modela broda

- Section Editor (SE): Interaktivni editor u kojem je moguće izraditi model trupa broda ili bilo koji njegov dio. Unos podataka može se vršiti numerički ili se model može crtati direktno na ekranu, a moguća je i kombinacija ove dvije metode.
- Part Maker (PM): Dio programa u kojem se može izraditi bilo koji dio modela (uključujući i sam trup), ali se obično koristi za izradu privjesaka, tankova i nadgrađa modela broda izrađenog u Section Editoru. Također nam omogućava i mijenjanje veličine modela u izabranom omjeru.
- Appendage Maker (AM): Programski alat za izradu detalja, kao npr. kobilice, kormila, tunela osovinskog voda, pramčanih propulzora, preluka palube, definiranje debljine oplate, itd. Kako nema ograničenja oblika, veličine ili složenosti moguće je izraditi bilo koji dio modela ili čak i sam model. Uključuje naredbe za spajanje dijelova modela.
- Tank Maker (TM): Sadrži programske alate za izradu tankova ili drugih pregrada broda.

- Display: Omogućava prikaz modela broda na ekranu u tlocrtu, bokocrtu, izometriji i po pojedinim dijelovima, te ispis na printeru.
- Hull Maker (HM): Dio prilagođen izradi trupa.
- Model Converter (MC): Pomoćni program za konvertiranje oblika izlazno/ulaznih podataka forme u svrhu izmjene između različitih specijaliziranih programa.

Programski alati za obradu modela broda

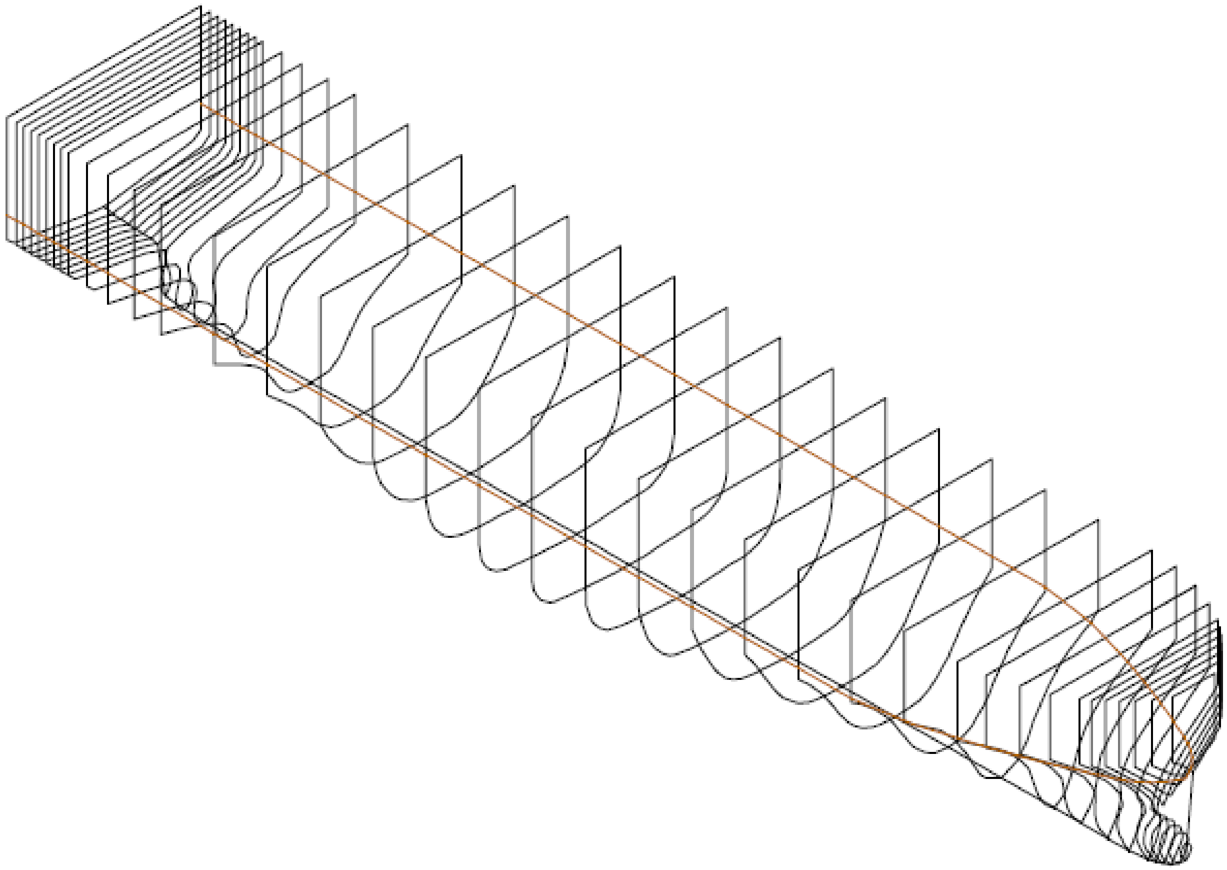
- Main program (GHS): Glavni program omogućava proračun hidrostatičkih značajki broda, stabiliteta u neoštećenom i oštećenom stanju, uključujući utjecaj tankova.
- Load Editor (LE): Omogućava brzo i lako krcanje tankova i drugih težina s istovremenim odzivom na gaz, trim i stabilitet broda.
- Longitudinal Strength (LS): Računa poprečne sile, momente savijanja i krivulju progiba strukture broda, s ili bez utjecaja valova,
- Tank Soundings (TS): Računa i ispisuje tablicu sondiranja tankova u nekoliko prilagođenih oblika.
- Surface Areas (SA): Računa veličinu oplakane površine broda, te položaj njegova težišta.
- Advanced Features (AF): Računa indeks pregrađivanja za brodove za prijevoz suhih tereta prema propisima IMO organizacije.

3.2. Modeliranje forme

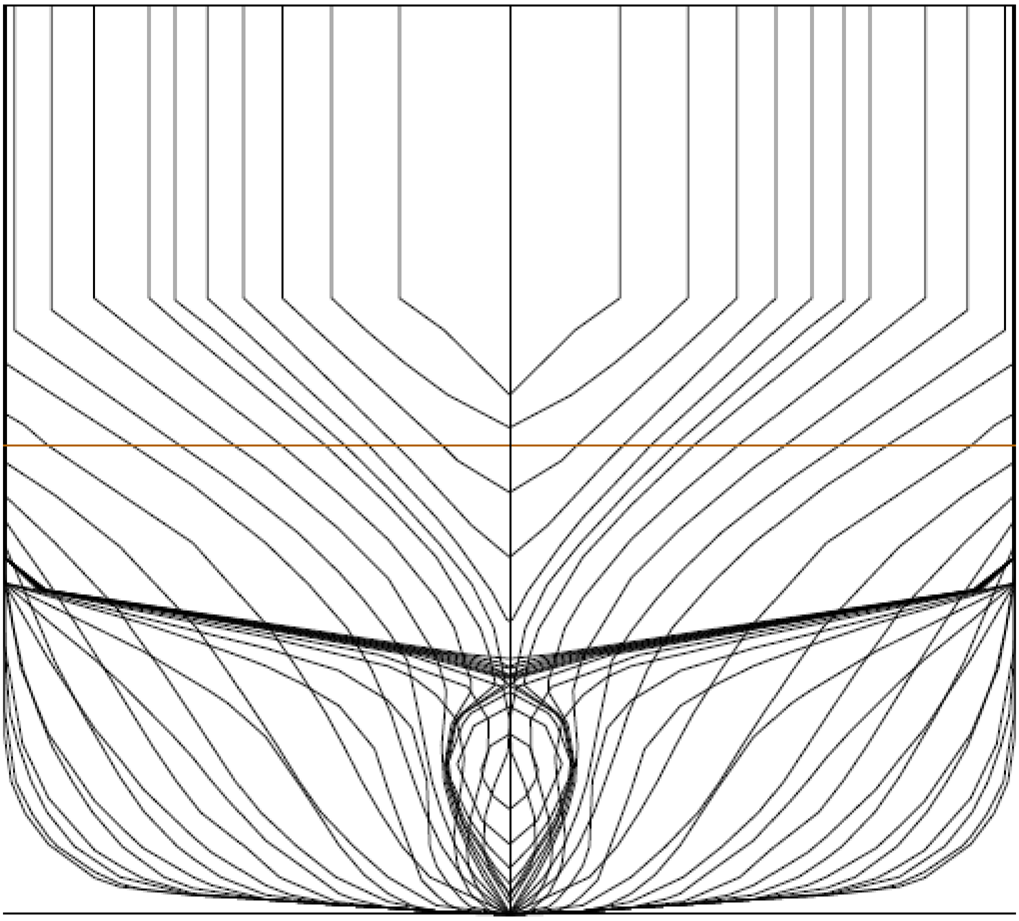
Dobivena digitalna forma iz prethodno navedenih izvora smatrana je nedovoljno preciznom, te je stoga prvi zadatak bio modelirati ispravnu formu. To je učinjeno koristeći program General Hydrostatics, GHS.

Linije broda crtaju se u pomoćnom programu nazvanom "Section Editor" (kratica SE), tako da se numerički unose koordinate točaka pojedinih rebara koje program spaja pravcima. Zbog nedovoljnog broja numerički upisanih točaka potrebno je umetanjem dodatnih točaka finije opisati formu rebara. Umetanje i smještanje dodatnih točaka radi se grafičkom metodom izravno na ekranu uz korištenje tipkovnice

Linije broda definirane u pomoćnom programu SE unose se u pomoćni program "Part Maker" (kratica PM) u kojem se izrađene linije broda mogu prikazati na ekranu u tlocrtu, bokocrtu, izometriji i kao nacrt rebara. Za ispravljanje mogućih grešaka u definiranju linija broda potrebno se vratiti u program SE. [Slika 3. i Slika 4.]



Slika 3. Izometrijski prikaz modificirane forme



Slika 4. Linije modificirane forme

3.3. Definiranje podjele unutrašnjih prostora broda

Nakon što se definiraju linije broda potrebno je definirati i podjelu unutrašnjeg prostora broda. Prostori omeđeni vodonepropusnim pregradama se pri proračunu stabiliteta broda u oštećenom stanju smatraju tankovima iako im to ne mora biti prvobitna namjena. Za svaki prostor zadaje se:

- Položaj po duljini, visini i širini broda.
- Oblik stjenki koje ga omeđuju.
- Koeficijent naplavljivosti [Tablica 6. i Tablica 7.]
- Vrsta tekućine koja ga naplavljuje za slučaj oštećenja i njezina gustoća.
- Vrsta tereta i njegova gustoća (za tankove).

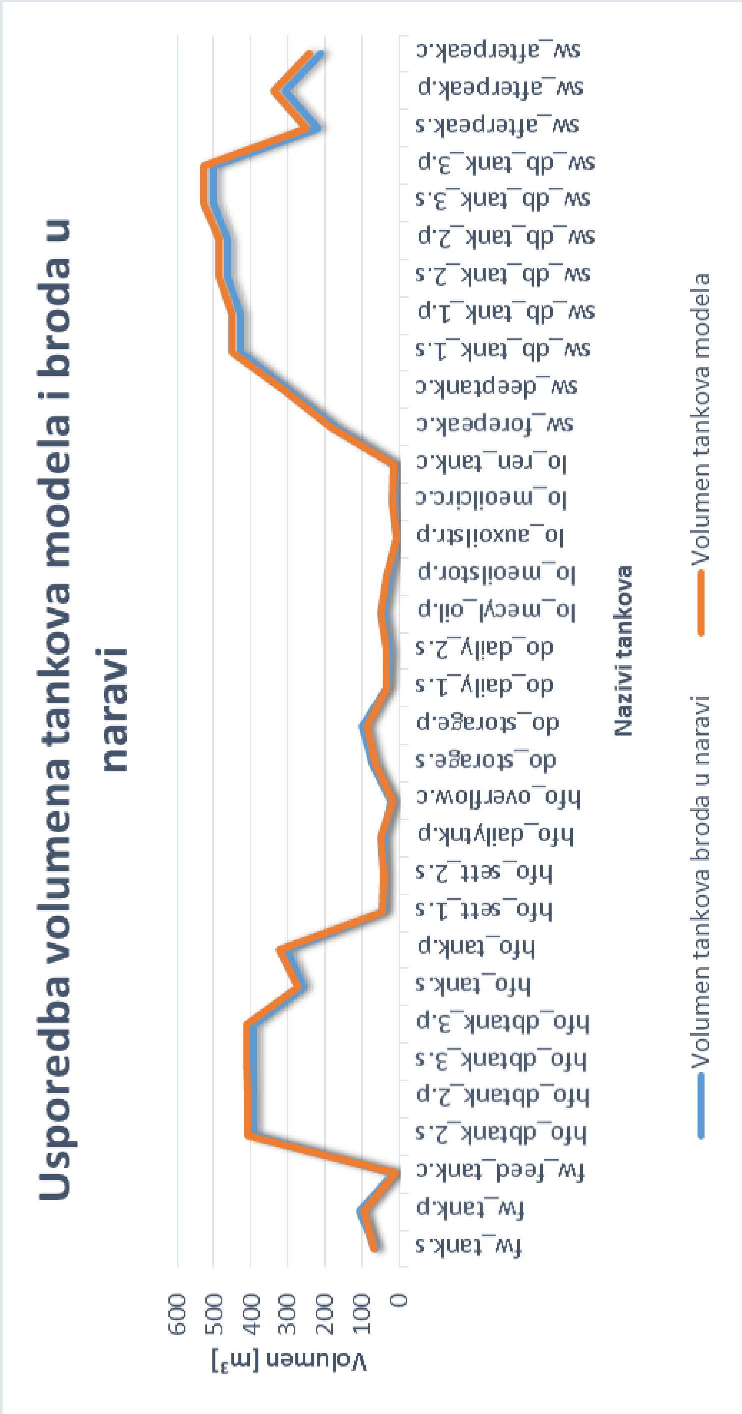
Linije broda zajedno s definiranim prostorima tvore datoteku koja sadrži naziv datoteke s ekstenzijom "rf" (run file), npr. "tanks.rf". Pokretanjem datoteke "tanks.rf" u pomoćnom programu PM dobije se konačni model broda čiji prikaz se provjeri na ekranu. [Slika 5.] Tako prikazan model broda s podjelom prostora snima se kao jedan geometrijski oblik tj. grafička datoteka "cart.gf" kojom će se vršiti daljnja analiza modela u glavnom programu GHS.

tanks3.rf - Notepad

File Edit Format View Help

```
read car3.gf

enter pm

create fw_tank.p
perm 0.95
cont fw
ends -3,-11.4
out 5.25
bot 8.81
top 11.41
fit hull
/

create fw_tank.s
perm 0.95
cont fw
ends -3,-11.4
out 3.125
bot 8.81
top 11.41
fit hull
/

create fw_feed_tank.c
perm 0.95
cont fw
ends -11.4,-13.95
out 1.25
bot 6.17
top 8.81
fit hull
/
```

Slika 5. Isječak definicije tankova



Slika 6. Usporedba volumena tankova modela i broda u naravi

Kad pogledamo usporedbu volumena tankova modela i volumena tankova broda [Slika 6.] uviđamo da su razlike relativno male [Tablica 1.], te da je definicija tankova zadovoljavajuća.

Tablica 1. Volumen tankova i odstupanje od dokumentacije

Naziv tanka	Volumen tankova modela m^3	Volumen tankova po projektnoj dokumentaciji m^3	Odstupanje
Fresh water tank SB	64,84	69,81	-7,1%
FRESH WATER TANK PS	108,93	97,74	11,4%
Feed Water tank	14,30	11,30	26,5%
Double bottom tk N.2 SB C FO	393,80	410,60	-4,1%
Double bottom tk N.2 PS C FO	393,80	410,60	-4,1%
Double bottom tk N.3 SB C FO	395,40	413,19	-4,3%
Double bottom tk N.3 PS C FO	395,40	413,19	-4,3%
HFO bunkr tank SB	259,70	275,53	-5,7%
HFO bunkr tank PS	304,14	324,17	-6,2%
HFO settling tank SB	44,43	49,14	-9,6%
HFO settling tank PS	44,43	44,53	-0,2%
HFO daily tank	44,43	49,63	-10,5%
FO overflow tank	22,44	19,38	15,8%
DO storage tank SB	73,44	66,38	10,6%
DO storage tank PS	99,86	88,66	12,6%
DO daily tank N.1	34,65	36,73	-5,7%
DO daily tank N.2	27,92	35,51	-21,4%
M.E. cyl. Oil tank	45,13	53,08	-15,0%
M.E. LO storage tank	28,79	36,76	-21,7%
AUX.E LO storage tank	8,57	10,64	-19,5%
M.E. LO circ. tank	18,20	18,62	-2,3%
Renovating LO tank	16,13	18,13	-11,0%
Fore peak WB	174,92	184,84	-5,4%
Deep tank WB	302,79	314,28	-3,7%
Double bottom tk N.1 SB WB	428,57	450,84	-4,9%
Double bottom tk N.1 PS WB	428,57	450,84	-4,9%
Double bottom tk N.2 SB WB	462,71	485,98	-4,8%
Double bottom tk N.2 PS WB	462,71	484,86	-4,6%
Double bottom tk N.3 SB WB	503,80	527,71	-4,5%
Double bottom tk N.3 PS WB	503,80	528,19	-4,6%
After peak SB WB	220,32	250,59	-12,1%
After peak PS WB	308,70	372,96	-17,2%
After peak C WB	273,40	310,24	-11,9%
Separating sludge tank	16,66	16,30	2,2%
Bilge W. Collecting tank	47,78	46,50	2,7%
Stern tub. O. Drain	7,85	7,60	3,3%
FO & LO drain tank	17,97	15,40	16,7%
SEWAGE HOLDING TANK	15,84	13,60	16,5%
Suma volumena:	7015,10	7414,04	-5,4%

3.4. Definiranje knjižnične datoteke

U glavnom programu GHS naredbe se u načelu unose utipkavanjem. Kako bi se ubrzao postupak, i povećao stupanj automatizacije proračuna, generirana je knjižnična datoteka s ekstenzijom ".lf". Ona u sebi sadržava MACRO naredbe kojima se skraćuje sadržaj izvršne datoteke. Na te naredbe se veoma jednostavno pozvati pri kreiranju izvršne datoteke naredbom ."naziv_MACRO_naredbe" Knjižnična datoteka "library.lf" u sebi sadrži:

- MACRO STABLIM za definiciju kriterija stabiliteta neoštećenog broda [Slika 7.]. Ovi kriteriji su korišteni pri proračunu stabiliteta za neoštećen brod.
- MACRO DAMLIM za definiciju kriterija stabiliteta oštećenog broda [Slika 7.]. Ovi kriteriji su korišteni pri proračunu stabiliteta oštećenog broda, te su dobiveni iz pravila [9].
- MACRO DAMCON
- MACRO DIVISION za podjelu prostora definiranih u "tanks.rf" datoteci na 6 dijelova. [Slika 7. i Tablica 2.] Svaki odjeljak je definiran s poprečnim pregradama. Karakteristični brod je podijeljen na 7 poprečnih odjeljaka, ali radi realnosti, krmeni odjeljci koji se protežu duljinom skladišta 4 zadržani su kao jedan odjeljak umjesto dva.
- MACRO CRTPTSAL s opisom kritičnih točaka broda [Slika 8.]. Svaka kritična točka definirana je svojim položajem (LCG, VCG, TCG) i opisom. Opisi variraju od:
    - FLOOD (točka doprinosi progresivnoj naplavi) jedinično stanje, točka koja nije nikakva prepreka prodoru vode. Obično su to ventilacijski otvori visoko na brodu, npr. dovod zraka motoru.
    - TIGHT (točka doprinosi progresivnoj naplavi samo ukoliko je u ravnotežnom stanju nakon oštećenja potopljena) ove točke su nepropusne na vremenske uvijete, ali nisu vodonepropusne
    - NOFLOOD (točka ne doprinosi progresivnoj naplavi) ove točke se smatraju vodonepropusnima.

- MACRO STOR definicije zaliha: 10% i 100% zaliha, te MACRO ADD posade i provijanta [Slika 8. i Slika 9.]. Zalihe su definirane punjenjem tankova u kojima se skladište. Svakom tanku je pridodana vrijednost gustoće sadržaja te volumni postotak sadržaja unutar tanka.
- MACRO BALLAST definicije krcanja balasta za sva potrebna stanja. Koristimo četiri stanja krcanja balasta:
    - Balastno stanje pri 100% zaliha
    - Balastno stanje pri 10% zaliha
    - Balastiranje pri homogenom stanju krcanja uz 100% zaliha
    - Balastiranje pri homogenom stanju krcanja uz 10% zaliha
- MACRO HOLDS definicije krcanja tereta [Slika 9.]. Definirani su samo skladišni prostori ispod palube čvrstoće, no teret nakrcan u njih odgovara karakterističnom brodu. Teret je zatim rasprostranjen duž duljine skladišnih prostora kako bi se simulirala raspodjela mase automobila po palubama unutar skladišta. To je polučilo veoma dobre rezultate u definiciji tereta te je greška manja od 1%. Slična stvar je učinjena i u definiciji provijanta i posade, pošto su te dvije stavke trebale biti definirane kao težine, a ne volumen krcanja fluida u takovima. Također su rasprostranjene po dužini, sa zadržanim vrijednostima VCG, LCG i TCG.
- MACRO FLOOD# definicije oštećivanja tankova potrebnih za deterministički proračun, koje tvore ukupno 54 slučaja oštećenja broda [Slika 9.]. Svaki FLOOD MACRO je definiran sa popisom oštećenih tankova. Podijeljeni su u dvije skupine:
    - Oštećenje svih tankova i prostora unutar odjeljka
    - Oštećenja svih tankova i prostora unutar odjeljka izuzevši skladišni prostor tog odjeljka, strojarnicu i prostoriju sa kormilarskim strojem (u slučaju prvog odjeljka).

```
MACRO STABLIM
limit off
limit title IMO A.167 Stability
limit gm upright > 0.15
limit area from 0 to 30 > 0.055
limit area from 0 to 40 or fld > 0.09
limit area from 30 to 40 or fld > 0.03
limit ra at 30 > 0.2
limit angle at max > 25
/

MACRO DAMLIM
limit off
limit title Damage Stability
limit absolute angle at equil < 25
limit angle from equil to ra0 > 20
limit ra at max > 0.1
limit area from equil to ra0 > 0.0175
/

MACRO DAMCON
solve
page
status WE TA DR DI CRT /fsm /noref
hs
ra 0,2.5,...,50 /limit:ATT /area /free /fsm /nowarn /stop: ra
/

MACRO DIVISION
divisions  off
div (1)
hold_4.c,steering.c,strojarnica.c,sludge_tank.c,bilge_tank.c,stern_oil_dr.c,oil
_dr_tank.s,sw_afterpeak.s,sw_afterpeak.p,sw_afterpeak.c,lo_mecyl_oil.p,lo_meoil
stor.p,lo_auxoilstr.p,lo_meoilcirc.c,lo_ren_tank.c,do_storage.s,do_storage.p,do
_daily_1.s,do_daily_2.s,hfo_tank.s,hfo_tank.p,hfo_sett_1.s,hfo_sett_2.s,hfo_dai
lytnk.p,hfo_overflow.c,fw_tank.s,fw_tank.p,fw_feed_tank.c
div (2) hold_3.c,sw_db_tank_3.p,hfo_dbtank_3.p,sw_db_tank_3.s,hfo_dbtank_3.s
div (3) hold_2.c,sw_db_tank_2.p,hfo_dbtank_2.p,sw_db_tank_2.s,hfo_dbtank_2.s
div (4) hold_1.c,sw_db_tank_1.p,sw_db_tank_1.s
div (5) eq_domestic.c,bowthrust.c,sw_deeptank.c,sewage_tank.c
div (6) sw_forepeak.c,voidspace.c,bosuns.c
divisions
/
```

Slika 7. 1. Isječak iz knjižnične datoteke

```
MACRO CRTPTSAL
`                        KRITICNE TOCKE
`Weathertight kriticne tocke koje nisu Watertight
CRTpt (1)  "AirPipe AP SB"          9.900,15.100,15.260    /TIGHT
CRTpt (2)  "AirPipe AP PS"          9.900,-15.100,15.260   /TIGHT
CRTpt (3)  "AirPipe FreshW SB"    -11.110,15.100,15.260    /TIGHT
CRTpt (4)  "AirPipe FreshW PS"    -11.110,-15.100,15.260   /TIGHT
CRTpt (5)  "AirPipe DB 3 SB"      -39.250,15.130,15.260    /TIGHT
CRTpt (6)  "AirPipe DB 3 PS"      -39.250,15.130,15.260    /TIGHT
CRTpt (7)  "AirPipe DB 2 SB"     -114.680,14.950,15.260    /TIGHT
CRTpt (8)  "AirPipe DB 2 PS"     -118.920,-14.950,15.260   /TIGHT
CRTpt (9)  "AirPipe DB 1 SB"     -144.400,12.060,15.260    /TIGHT
CRTpt (10)  "AirPipe DB 1 PS"    -144.400,-12.060,15.260   /TIGHT
CRTpt (11)  "AirPipe FP"         -158.750,-10.150,18.710   /TIGHT
CRTpt (12)  "Weath Door Domest"  -157.650,-0.600,14.910    /TIGHT
CRTpt (13)  "Weath Door Bosuns"  -157.650,1.400,14.910     /TIGHT
`Non-Weathertight kriticne tocke
CRTpt (14)  "ER Vent 1 SP"        -18.200,15.550,21.910
CRTpt (15)  "ER Vent 1 PS"        -18.200,-15.550,21.910
CRTpt (16)  "ER Vent 2 SB"        -33.500,15.550,21.910
CRTpt (17)  "ER Vent 2 PS"        -25.000,-15.550,21.910
/

MACRO STOR100
content (DO*)   do 0.86
content (HFO*) hfo 0.96
content (LO*)   lo 0.9
content (SW*)   lo 1.025
content (FW*)   fw 1.0
load (DO*)  95%
load (HFO*) 95%
load (FW*)  95%
load (LO*)  95%
load (bilge_tank.c)    10%
load (stern_oil_dr.c)  10%
load (oil_dr_tank.s)   85%
load (sewage_tank.c)    5%
load (lo_ren_tank.c)   70%
load (lo_meoilcirc.c)  75%
load (hfo_overflow.c)  77%
/
```

Slika 8. 2. Isječak iz knjižnične datoteke

```
MACRO HOLDS
ADD "hold_1.c", 37.689@-120.2,37.689@-160.45, 0., 19.76
ADD "hold_2.c", 57.273@-79.4,57.273@-120.2, 0., 15.69
ADD "hold_3.c", 56.598@-38.6,56.598@-79.4, 0., 15.68
ADD "hold_4.c", 31.543@4.635,31.543@-38.6, 0., 20.76
/

MACRO CREW100
ADD "CREW & EFFECTS" 0.06839@-110,0.06839@-146.55, 0., 29.3
ADD "PROVIANT" 1.5686@-116.8,1.5686@-124.45, 0., 29.2
/

MACRO CREW10
ADD "CREW & EFFECTS" 0.06839@-110,0.06839@-146.55, 0., 29.3
ADD "PROVIANT" 0.2614@-116.8,0.2614@-124.45, 0., 29.2
/

MACRO FLOOD1
type (sludge_tank.c) DAMAGED
type (bilge_tank.c) DAMAGED
type (stern_oil_dr.c) DAMAGED
type (oil_dr_tank.s) DAMAGED
type (sw_afterpeak.s) DAMAGED
type (sw_afterpeak.c) DAMAGED
type (lo_meoilcirc.c) DAMAGED
type (lo_ren_tank.c) DAMAGED
type (do_storage.s) DAMAGED
type (do_daily_1.s) DAMAGED
type (do_daily_2.s) DAMAGED
type (hfo_tank.s) DAMAGED
type (hfo_sett_1.s) DAMAGED
type (hfo_sett_2.s) DAMAGED
type (hfo_overflow.c) DAMAGED
type (fw_tank.s) DAMAGED
type (fw_feed_tank.c) DAMAGED
/
```

Slika 9. 3. Isječak iz knjižnične datoteke

Tablica 2. Definicija odjeljaka

```
                  DIVISION definitions

Division---Fwd End---Aft End----Wing---HBhd---Parts---------
 1           38.600f    3.900a                HOLD_4.C STEERING.C
                                              STROJARNICA.C
                                              SLUDGE_TANK.C
                                              BILGE_TANK.C
                                              STERN_OIL_DR.C
                                              OIL_DR_TANK.S
                                              SW_AFTERPEAK.S
                                              SW_AFTERPEAK.P
                                              SW_AFTERPEAK.C
                                              LO_MECYL_OIL.P
                                              LO_MEOILSTOR.P
                                              LO_AUXOILSTR.P
                                              LO_MEOILCIRC.C
                                              LO_REN_TANK.C
                                              DO_STORAGE.S
                                              DO_STORAGE.P
                                              DO_DAILY_1.S
                                              DO_DAILY_2.S
                                              HFO_TANK.S HFO_TANK.P
                                              HFO_SETT_1.S
                                              HFO_SETT_2.S
                                              HFO_DAILYTNK.P
                                              HFO_OVERFLOW.C
                                              FW_TANK.S FW_TANK.P
                                              FW_FEED_TANK.C
 2           79.400f   38.600f                HOLD_3.C
                                              SW_DB_TANK_3.P
                                              HFO_DBTANK_3.P
                                              SW_DB_TANK_3.S
                                              HFO_DBTANK_3.S
 3          120.200f   79.400f                HOLD_2.C
                                              SW_DB_TANK_2.P
                                              HFO_DBTANK_2.P
                                              SW_DB_TANK_2.S
                                              HFO_DBTANK_2.S
 4          146.550f  120.200f                HOLD_1.C
                                              SW_DB_TANK_1.P
                                              SW_DB_TANK_1.S
 5          158.450f  146.550f                EQ_DOMESTIC.C
                                              BOWTHRUST.C
                                              SW_DEEPTANK.C
                                              SEWAGE_TANK.C
 6          168.050f  158.450f                SW_FOREPEAK.C
                                              VOIDSPACE.C BOSUNS.C
Distances in METERS.----------------------------------------
```

3.5. Proračun stabiliteta unutar programskog sučelja

Proračun stabiliteta broda u oštećenom stanju vrši se vjerojatnosnom metodom prema pravilima [5] u glavnom programu naredbom DAMSTAB /SDI216C (Subdivision Index for Cargo Vessels, IMO MSC.216(82)). Naredba DAMSTAB primjenjuje metodu ocjene stabiliteta oštećenog broda. Ova vjerojatnosna metoda za proračun vjerojatnosti preživljavanja oštećenja uzima u obzir ne samo stabilitet broda kod oštećenja izvjesnog broja odjeljaka, već daje i vjerojatnosti različitih opsega oštećenja kao i vjerojatnosti njihovog preživljavanja. Za sve moguće kombinacije naplavljivanja umnošci vjerojatnosti se zbrajaju i dobiveni rezultat predstavlja postignuti indeks pregrađivanja *A*.

Prije početka proračuna (tj. izdavanja naredbe DAMSTAB /SDI216C) program mora imati uputu koje kombinacije tankova i odjeljaka se smatraju kao jedna podjela. To ne podrazumijeva da svaki tank ili odjeljak predstavlja jednu neovisnu podjelu. Ove informacije moraju se osigurati pomoću naredbe DIVISION, koju smo radi jednostavnosti unijeli preko knjižnične datoteke. Nakon što se definiraju sve podjele, može se proračunati indeks pregrađivanja za postojeće stanje krcanja. DAMSTAB naredba proračunava i prikazuje oštećenja i vjerojatnost preživljavanja za svaki slučaj oštećenja, a zatim zbraja rezultate, prikazujući postignuti indeks pregrađivanja *A*. Treba naglasiti da se ovaj indeks odnosi samo na postojeće stanje krcanja, te se za svako drugo stanje, indeks (naravno uz ponovno izdavanje naredbe DAMSTAB /SDI216C) mora ponovo proračunati.

U izlaznoj tablici svaki redak predstavlja oštećenje izvjesnog odjeljka ili kombinacije odjeljaka, odnosno drugim riječima svaki redak predstavlja jedan pozitivni doprinos *dA* stvarnom postignutom indeksu pregrađivanja *A*. Krajnji lijevi stupac pokazuje odjeljke koji su oštećeni. Podjele su numerirane u skladu s preporukama DIVISION naredbe. Sljedeći stupac označen s *p* predstavlja vjerojatnost oštećenja pojedinog odjeljka ili kombinacije odjeljaka, dok stupac do njega označen sa *s* predstavlja vjerojatnost preživljavanja oštećenja odjeljka ili kombinacije odjeljaka.

Umnožak $p \cdot s$ prikazan je u sljedećem stupcu, dok stupac do njega prikazuje postignuti indeks pregrađivanja izvjesnog odjeljka ili kombinacije odjeljaka koji je samo zbroj $p \cdot s$ vrijednosti. Na desnoj strani nalazi se pet stupaca, koji pokazuju najznačajnije karakteristike svakog slučaja oštećenja. To su gaz, trim i nagib (ove dvije zadnje veličine izražene su u stupnjevima) koji predstavljaju vodnu liniju u ravnotežnom oštećenom položaju. Zadnja dva stupca predstavljaju opseg krivulje pozitivnog stabiliteta, kao i najveću polugu u ovom opsegu.

Prilikom razmatranja slučaja oštećenja jednog od odjeljaka u brodu, često je potrebno pretpostaviti da će oštećenje obuhvatiti jedan ili više tankova koji mogu biti prisutni na jednoj strani odjeljka, ali ne nužno i ostale tankove koji mogu biti dovoljno daleko od pretpostavljenog mjesta oštećenja. Također mogu postojati i uzdužne pregrade koje mogu ostati neoštećene ili mogu biti probijene. Stoga bi bilo dobro sa stanovišta analiziranja slučaja oštećenja uključiti više od jedne grupe tank/odjeljak. Zbog toga je i namjena DIVISION naredbe da se takvoj skupini tank/odjeljak pridruži broj, tako da se ostale naredbe mogu zgodno primijeniti na takve podjele. Na kraju se može reći još i to da DIVISION naredba ne kreira granice stvarnih tankova, već ona samo pridružuje broj podjele takvom tanku ili grupi odjeljaka.

4. PRAVILA KLASIFIKACIJSKOG DRUŠTVA BUREAU VERITAS ZA STABILITET BRODA U OŠTEĆENOM STANJU

4.1. Općenito

Metacentarske visine *GM*, poluge stabiliteta *GZ* i položaji težišta računaju se prema metodi konstantne istisnine. U determinističkom pristupu izrađuje se skupina slučajeva oštećenja (eng.: Damage cases), čiji broj, kao i broj odjeljaka uključenih u svaki od slučajeva, ovisi o dimenzijama broda i unutrašnjem rasporedu. Za svako stanje krcanja razmatra se svaki slučaj oštećenja. Vjerojatnosni pristup uzima vjerojatnost preživljavanja nakon sudara kao mjeru sigurnosti broda u oštećenom stanju (eng.: "attained subdivision index *A"*). Proračuni se vrše pri određenim gazovima i vrijednostima *GM* kako bi se dobila najmanja *GM* krivulja pri kojoj postignuti indeks pregrađivanja *A* udovoljava minimalnoj razini sigurnosti tj. zahtijevanom indeksu pregrađivanja *R* (eng.: "required subdivision index *R*").[9]

4.2. Dokumenti potrebni za proračun stabiliteta u oštećenom stanju determinističkom metodom

U sklopu proračuna stabiliteta u oštećenom stanju potrebno je predočiti sljedeće dokumente:

- popis karakteristika (volumen, težište mase, faktor naplavljivosti) svakog odjeljka koji može biti oštećen,
- tablicu otvora u pregradama, palubama i bokovima, te detaljne podatke o njima,
- popis slučajeva oštećenja,
- detaljni rezultati proračuna stabiliteta u oštećenom stanju,
- granična GM/KG krivulja ako je predviđeno,
- opći plan,
- uređaji za odvod (putnički brodovi),
- raspored vodonepropusnih vrata i vrata nepropusnih za vremenske uvijete, proračun tlakova i
- cijevi i oštećeno područje kad pucanje tih cijevi izaziva progresivnu naplavu.

Progresivno naplavljivanje je dodatno naplavljivanje prostora koji se nisu smatrali oštećenima (kroz otvore, cijevi, evakuacijske puteve, ventilacijske vodove itd...). [9]

4.3. Dodatna dokumentacija za proračun stabiliteta u oštećenom stanju za vjerojatnosni pristup

- pregradna duljina L_s ,
- inicijalni gaz i pripadne *GM* vrijednosti,
- zahtijevani indeks pregrađivanja *R*,
- dobiveni indeks pregrađivanja *A* s tablicom doprinosa svake oštećivane zone,
- gaz, trim i *GM* u oštećenom stanju,
- opseg oštećenja i definicija slučajeva oštećenja s pripadajućim vrijednostima *p*, *v* i *r*,
- poluga stabiliteta s faktorom preživljavanja *s*,
- popis kritičnih mjesta nepropusnih na vremenske uvijete, s pripadnim kutom urona i
- detalji naplavljenih prostora s količinama naplavljene vode / izgubljenog uzgona, s pripadnim težištima [9]

4.4. Veličine oštećenja

Poprečno oštećenje mjeri se od unutrašnje strane oplate boka do simetrale pod pravim kutom, na ljetnoj vodnoj liniji. Vertikalno oštećenje mjeri se od unutrašnje strane oplate dna na simetrali. [Tablica 3.]

Tablica 3. Opseg oštećenja

Mjesto oštećenja	Uzdužna duljina oštećenja	Poprečna duljina oštećenja	Vertikalna duljina oštećenja
Bok	$lc = 1/3\ L_{LL}^{2/3}$ ili 14,5 m (1)	$tc = B/5$ ili 11,5 m (1)	vc = NO LIMIT
Dno - za 0.3 L_{LL} od Pramčane okomice	$ls = 1/3\ L_{LL}^{2/3}$ ili 14,5 m (1)	$ts = B/6$ ili 10 m (1)	$vs = B/15$ ili 6 m (1)
Dno - bilo koji drugi dio	$ls = 1/3\ L_{LL}^{2/3}$ ili 5 m (1)	$ts = B/6$ ili 5 m (1)	$vs = B/15$ ili 6 m (1)

(1) manja vrijednost

Tablica 4. Standard oštećivanja

Duljina broda m	Oštećenje bilo gdje po duljini broda	Oštećenje između poprečnih pregrada	Naplavljena strojarnica
$L_{LL} \leq 100$	NE	DA (1) (2)	NE
$100 \leq L_{LL} \leq 150$	NE	DA (1)	NE
$150 \leq L_{LL} \leq 225$	DA	NE	DA, jedino strojarnica
$L_{LL} \geq 225$	DA	NE	DA

(1) strojarnica nije naplavljena

(2) izuzeća nekih zahtjeva mogu biti prihvaćena od klasifikacijskog društva u pojedinim slučajevima

Tablica 5. Opseg oštećenja dna

Nosivost	Uzdužna duljina oštećenja	Poprečna duljina oštećenja	Vertikalna duljina oštećenja
< 75000 t	0,4 L_{LL} (1)	B/3	(2)
≥ 75000 t	0,6 L_{LL} (1)	B/3	(2)

(1) Mjereno od pramčane okomice

(2) Proboj vanjske oplate

Tablica 6. Propisani faktori naplavljivosti određenih tankova na brodu

Odjeljak	**Naplavljivost**
Zalihe	0,60
Smještaj	0,95
Strojevi	0,85
Prazno	0,95
Potrošne tekućine	0 – 0,95 (1)
Ostale tekućine	0 – 0,95 (1)

(1) u slučaju djelomično popunjenih odjeljaka – u skladu s količinom tekućine u odjeljku

Tablica 7. Propisani faktori naplavljivosti teretnih prostora na brodu

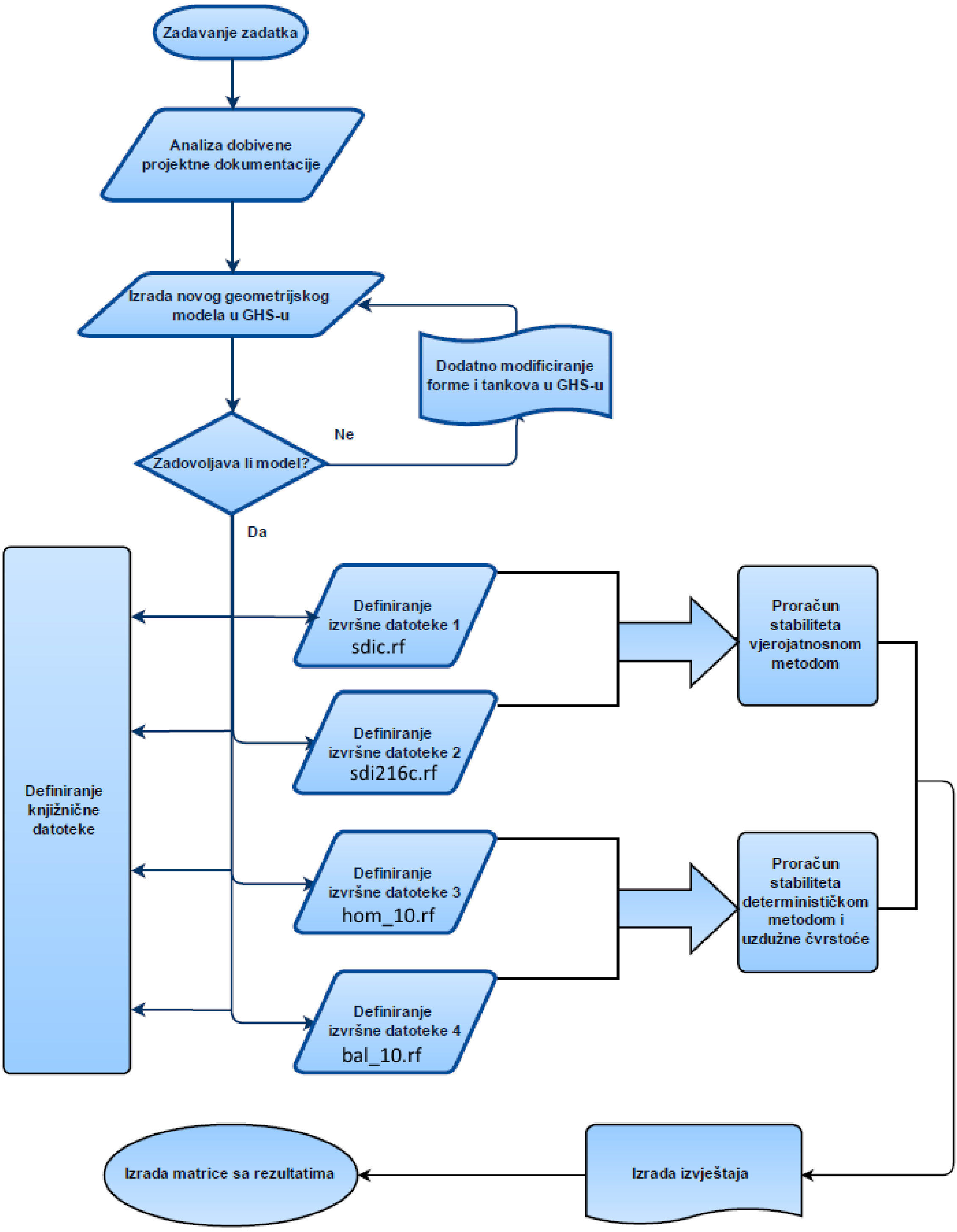
Odjeljak	Naplavljivost pri gazu		
	d_S	d_P	d_L
Suhi teret	0,7	0,8	0,95
Kontejnerski teret	0,7	0,8	0,95
Ro-ro teret	**0,9**	**0,9**	**0,95**
Tekući teret	0,7	0,8	0,95

4.5. Kriteriji stabiliteta u oštećenom stanju

Pri proračunu stabiliteta u oštećenom stanju brod mora zadovoljiti sljedeće kriterije:

- krajnja vodna linija mora biti ispod donjeg ruba otvora kroz koji može doći do progresivnog naplavljivanja
- kut nagiba uslijed nesimetrične naplave ne smije preći 25°, eventualno do 30° ako paluba ne uranja
- stabilitet se može smatrati dovoljnim, ako krivulja poluge statičkog stabiliteta ima minimalno 20° rezerve iznad stanja ravnoteže, ako je u tom rasponu maksimalna preostala poluga stabiliteta *GZ* bar 0.1 m, a površina ispod krivulje u tom rasponu 0.0175 m-rad [6]

5. ALGORITAM POSTUPKA PRORAČUNA



Slika 10. Dijagram toka proračuna

6. PRORAČUN STABILITETA U OŠTEĆENOM STANJU DETERMINISTIČKOM METODOM I PRORAČUN UZDUŽNE ČVRSTOĆE BRODA

6.1. Odabir kritičnih stanja krcanja i slučajeva oštećenja

Kako bi se najbolje opisao brod u oštećenom stanju, za deterministički dio proračuna određena su dva stanja krcanja.

- Load Case 1 – Homogeno stanje krcanja s 10% zaliha
- Load Case 2 – Balastno stanje krcanja s 10% zaliha

Radi opsežnosti proračuna, većina rezultata detaljno je prikazana na CD-R disku u prilogu radu. Deterministički proračun sadrži 543 stranice za LC 1 i LC 2, dok su rezultati za neoštećeni brod dani u prilogu radu. Neoštećen brod je proširen sa još dva stanja krcanja. Razlog tome je usporedba s vjerojatnosnim rezultatima, koji se oslanjaju na LC 3, homogeno stanje krcanja sa 100% zaliha. To stanje odgovara vodnoj liniji određenom gazom d_S u pravilima, dok LC 2 odgovara vodnoj liniji d_L u pravilima.

- Load Case 3 – Homogeno stanje krcanja s 100% zaliha
- Load Case 4 – Balastno stanje krcanja s 100% zaliha

Za prethodna dva stanja krcanja određeno je ukupno 54 stanja oštećenja, čije se numeričke oznake kreću od 1-27 za LC 1 i od 31-57 za LC 2. Ono što je netipično za ovakav tip oštećenja je provjera stabiliteta oštećenog broda i pri oštećenju 3 susjedna tanka. Svako stanje oštećenja prikazano je iz tri različita pogleda: pogled sa boka izvana, presjek broda uzdužno uz prikaz tankova te pogled odozgo. U slučajevima oštećenja uzimano je u obzir oštećenja cijelog odjeljka, bez pripadnih tankova tereta i s pripadnim skladištima tereta (te strojarnice i prostorije sa kormilarskim strojem u slučaju oštećenja odjeljka 1). To je učinjeno kako bi se zorno prikazalo da su oštećenja skladišta tereta uistinu među najgorim mogućim oblicima oštećenja. S obzirom na nedostatak uzdužnih pregrada, te rijetkim poprečnim pregradama i velikim prostorima za naplavu, ro-ro brodovi su veoma ranjivi.

Rezultati proračuna stabiliteta uspoređeni su s kriterijima za stabilitet u oštećenom stanju klasifikacijskog društva Bureau Veritas. Određene su i kritične točke koje ne smiju doći ispod razine vodne linije kako bi se spriječilo naplavljivanje. Izrađeni su karakteristični dijagrami stabiliteta i uzdužne čvrstoće. Dijagramima su prikazane najveće vrijednosti momenata savijanja za pojedina stanja, njihovi položaji po duljini broda te odstupanja od vrijednosti najvećeg momenta za brod u neoštećenom stanju. U ovom poglavlju prikazani su rezultati proračuna za brod u stanju oštećenja 16 i 46, koja su među najkritičnijim stanjima oštećenja. Rezultati proračuna za ostala stanja oštećenja dani su u prilogu.

6.2. Stanje oštećenja 16

U stanju oštećenja 16 oštećeni su dva susjedna odjeljka, zajedno sa pripadajućim skladišnim prostorima [Slika 11.]. Dobiveni rezultati slijede. [Tablica 8.]

Tablica 8. Rezultati za stanje oštećenja 16

STANJE OŠTEĆENJA 16, HOMOGENO NATOVAREN BROD SA 10% ZALIHA	Divisioni 3 i 4	**Kriteriji stabiliteta u oštećenom stanju**			94374
		(1) Kut ravnoteže	< 25°	0,62°	
		(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	123,09°	
		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	4,191	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ =	> 0.0175 m-rad	4,7187	

Prikazani su sljedeći rezultati:

- Položaj broda i grafički prikaz naplavljenih tankova [Slika 11.] Vidimo da brod ima relativno velik pramčani trim u iznosu od 6,394% L_{pp} broda. Potopljeni su svi oštećeni tankovi.
- Tablica stanja krcanja broda, i popis svih masa, te popis oštećenih tankova [Tablica 10.]

Oštećeni tankovi su:

hold_2.c

sw_db_tank_2.s

hfo_dbtank_2.s

hold_1.c

sw_db_tank_1.s

- Tablica sa popisom aktivnih kritičnih točaka sa njihovom karakteristikom [Tablica 11.]

  Svaka kritična točka ima svoj opis. Jedinično stanje je FLOOD što znači da se ta točka smatra točkom progresivne naplave. Postoje još TIGHT i NOFLOOD opisi. TIGHT znači da se točka smatra vremenski nepropusnom, a propusnom za vodu, dok NOFLOOD znači da je točka vodonepropusna.

- Hidrostatičke karakteristike broda za stanje oštećenja 16 [Tablica 12.]
- Krivulje stabiliteta za stanje oštećenja 16 [Slika 12.]
- Radi potpunije slike, prikazani su i detaljni izračuni stabiliteta za stanje 16. [Tablica 13.]
- Karakteristike uzdužne čvrstoće za stanje oštećenja 16 [Slika 13.]

Zaključno, za stanje oštećenja 16 smatramo da udovoljava kriterijima stabiliteta u oštećenom stanju usprkos velikom pramčanom trimu. Moment savijanja u oštećenom stanju manji je od momenta savijanja pri neoštećenom stanju za 24,2%, a položaj je značajnije pomaknut prema krmi, za 23,81 m, na uzdužni položaj od 54,75 m od krmene okomice.

Iznos maksimalne smične sile je promijenio predznak i položaj, te je apsolutno veći za 59,16%. Hvatište maksimalne smične sile značajno se pomaklo za 40,52 m prema pramcu, na uzdužni položaj od 79,4 m od krmene okomice.

6.3. Stanje oštećenja 46

U stanju oštećenja 46 oštećeni su dva susjedna odjeljka, zajedno sa pripadajućim skladišnim prostorima [Slika 11.]. Za razliku od stanja oštećenja 16, baza za ovo stanje bio je LC 2, tj. balastno stanje sa 10% zaliha. Dobiveni rezultati slijede. [Tablica 9.]

Tablica 9. Rezultati za stanje oštećenja 46

	Divisioni 3 i 4 bez:	**Kriteriji stabiliteta u oštećenom stanju**			
STANJE OŠTEĆENJA 45, BALASTNO NATOVAREN BROD SA 10% ZALIHA	hold_1.c	(1) Kut ravnoteže	< 25°	1,55°	106575
	hold_2.c	(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	131,71°	
		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	4,994	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ =	> 0.0175 m-rad	6,5183	

Prikazani su sljedeći rezultati:

- Položaj broda i grafički prikaz naplavljenih tankova [Slika 14.] Vidimo da brod ima relativno velik pramčani trim u iznosu od 6,952% L_{pp} broda. Potopljeni su svi oštećeni tankovi.
- Tablica stanja krcanja broda, i popis svih masa, te popis oštećenih tankova [Tablica 14.] Oštećeni tankovi su:

  hold_2.c

  sw_db_tank_2.s

  hfo_dbtank_2.s

  hold_1.c

  sw_db_tank_1.s

- Tablica sa popisom aktivnih kritičnih točaka sa njihovom karakteristikom [Tablica 15.] Svaka kritična točka ima svoj opis:

  Jedinično stanje je FLOOD što znači da se ta točka smatra točkom progresivne naplave. Postoje još TIGHT i NOFLOOD opisi. TIGHT znači da se točka smatra vremenski nepropusnom, a propusnom za vodu, dok NOFLOOD znači da je točka vodonepropusna.

- Hidrostatičke karakteristike broda za stanje oštećenja 46 [Tablica 16.]
- Krivulje stabiliteta za stanje oštećenja 46 [Slika 15.]
- Radi potpunije slike, prikazani su i detaljni izračuni stabiliteta za stanje 46. [Tablica 17.]
- Karakteristike uzdužne čvrstoće za stanje oštećenja 46 [Slika 16.]

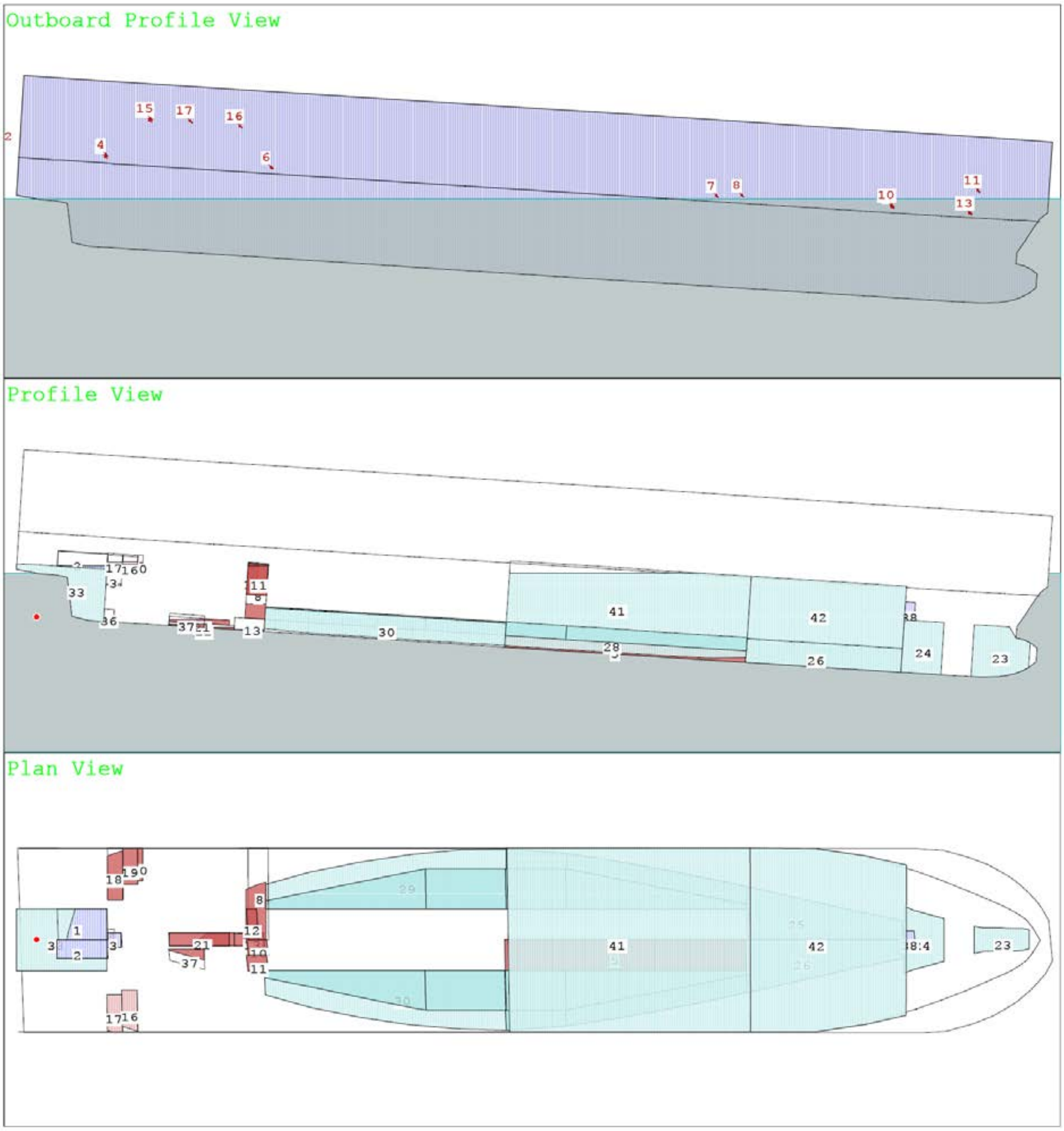
Zaključno, za stanje oštećenja 46 smatramo da udovoljava kriterijima stabiliteta u oštećenom stanju usprkos velikom pramčanom trimu. Moment savijanja u oštećenom stanju manji je od momenta savijanja pri neoštećenom stanju za 22,8%, a položaj je značajnije pomaknut prema krmi, za 14,36 m, na uzdužni položaj od 63,25 m od krmene okomice.

Iznos maksimalne smične sile je promijenio predznak i položaj, te je apsolutno veći za 13,16%. Hvatište maksimalne smične sile značajno se pomaklo za 40,57 m prema pramcu, na uzdužni položaj od 79,4 m od krmene okomice.

6.4. Prikaz proračuna za brod u stanju oštećenja 16

DAMAGE CONDITION 16: HOMOGENOUS LOADED, T=8.440 m, 10% STORES

CG - Draft: 7.460 @ 0.000 Trim: fwd 10.55/165.00 Heel: stbd 0.62 deg.



Slika 11. Grafički prikaz stanja oštećenja 16

Tablica 10. Lista kapaciteta i popis oštećenih tankova pri stanju oštećenja 16

DAMAGE CONDITION 16: HOMOGENOUS LOADED, T=8.440 m, 10% STORES

WEIGHT and DISPLACEMENT and CRITICAL POINT STATUS
Baseline draft: 7.460 @ Origin
Trim: Fwd 10.55/165.00, Heel: Stbd 0.62 deg.

Part	Load	SpGr	Weight(MT)	LCG	TCG	VCG	FSM
LIGHT SHIP			12,231.06	76.087f	0.040s	14.838	
hold_1.c			1,516.98	140.325f	0.000	19.760	
hold_2.c			2,336.74	99.800f	0.000	15.690	
hold_3.c			2,309.20	59.000f	0.000	15.680	
hold_4.c			1,363.76	16.983f	0.000	20.760	
CREW & EFFECTS			2.50	128.275f	0.000	29.300	
PROVIANT			2.00	120.625f	0.000	29.200	
Total Fixed--------->			19,762.24	77.758f	0.025s	15.827	
FW_TANK.P	0.060	1.000	6.54	9.247f	2.482p	8.948	70.4
FW_TANK.S	0.150	1.000	9.73	8.164f	1.586s	9.036	20.3
FW_FEED_TANK.C	0.070	1.000	1.12	12.863f	0.032s	6.269	3.2
HFO_TANK.P	0.210	0.960	61.32	36.961f	4.077p	3.345	201.0
HFO_SETT_1.S	1.000	0.960	42.65	36.900f	1.312s	8.790	0.0
HFO_SETT_2.S	0.950	0.960	40.52	36.912f	3.939s	8.659	4.7
HFO_DAILYTNK.P	1.000	0.960	42.65	36.050f	2.625p	8.790	0.0
HFO_OVERFLOW.C	0.090	0.960	1.94	36.784f	0.042s	0.150	4.2
DO_DAILY_1.S	0.340	0.860	10.13	15.300f	10.718s	9.559	49.4
DO_DAILY_2.S	0.420	0.860	10.08	12.739f	11.629s	9.851	40.9
LO_MECYL_OIL.P	0.370	0.900	15.03	12.740f	9.426p	9.494	89.4
LO_MEOILSTOR.P	0.420	0.900	10.88	15.289f	11.511p	9.777	41.2
LO_AUXOILSTR.P	0.390	0.900	3.00	16.932f	11.866p	9.762	10.2
LO_MEOILCIRC.C	0.760	0.900	12.45	28.315f	0.006s	1.040	6.2
LO_REN_TANK.C	0.140	0.900	2.03	31.561f	0.031s	0.146	4.5
SW_FOREPEAK.C	1.000	1.025	179.29	162.555f	0.000	4.698	0.0
SW_DEEPTANK.C	1.000	1.025	310.36	149.709f	0.000	5.429	0.0
SW_DB_TANK_1.P	1.000	1.025	439.28	130.905f	2.554p	2.437	0.0
SW_DB_TANK_2.P	1.000	1.025	474.28	96.332f	9.180p	2.075	0.0
SW_DB_TANK_3.P	1.000	1.025	516.39	62.041f	9.436p	2.058	0.0
SW_DB_TANK_3.S	1.000	1.025	516.39	62.041f	9.436s	2.058	0.0
SW_AFTERPEAK.C	1.000	1.025	216.70	6.223f	0.000	6.759	0.0
STERN_OIL_DR.C	0.090	0.924	0.73	12.316f	0.012s	0.228	0.8
OIL_DR_TANK.S	0.090	0.924	1.66	26.385f	2.300s	0.338	0.8
SEWAGE_TANK.C	1.000	1.000	15.21	147.400f	0.000	10.380	0.0
Total Tanks--------->			2,940.37	86.631f	1.937p	3.496	547.1
Total Weight-------->			22,702.61	78.907f	0.229p	14.230	

Part		SpGr	Displ(MT)	LCB	TCB	VCB
HULL		1.025	41,931.98	92.973f	0.088s	7.842
HFO_DBTANK_2.S	Balance	0.960	-378.05	99.703f	2.545s	1.109
SW_DB_TANK_1.S	Flooded	1.025	-439.28	130.905f	2.554s	2.437
SW_DB_TANK_2.S	Flooded	1.025	-474.28	96.332f	9.180s	2.075
HOLD_2.C	Flooded	1.025	-12,695.98	99.580f	0.061s	8.367
HOLD_1.C	Flooded	1.025	-5,240.67	132.028f	0.000	10.072
Total Displacement-->		1.026	22,703.73	79.347f	0.155p	7.372

Tablica 11. Popis kritičnih točaka

	Critical Points		LCP	TCP	VCP	Height
(1)	AirPipe AP SB	TIGHT	9.900a	15.100s	15.260	8.253
(2)	AirPipe AP PS	TIGHT	9.900a	15.100p	15.260	8.579
(3)	AirPipe FreshW SB	TIGHT	11.110f	15.100s	15.260	6.912
(4)	AirPipe FreshW PS	TIGHT	11.110f	15.100p	15.260	7.238
(5)	AirPipe DB 3 SB	TIGHT	39.250f	15.130s	15.260	5.115
(6)	AirPipe DB 3 PS	TIGHT	39.250f	15.130s	15.260	5.115
(7)	AirPipe DB 2 SB	TIGHT	114.680f	14.950s	15.260	0.303
(8)	AirPipe DB 2 PS	TIGHT	118.920f	14.950p	15.260	0.355
(9)	AirPipe DB 1 SB	TIGHT	144.400f	12.060s	15.260	-1.563
(10)	AirPipe DB 1 PS	TIGHT	144.400f	12.060p	15.260	-1.302
(11)	AirPipe FP	TIGHT	158.750f	10.150p	18.710	1.204
(12)	Weath Door Domest	TIGHT	157.650f	0.600p	14.910	-2.621
(13)	Weath Door Bosuns	TIGHT	157.650f	1.400s	14.910	-2.643
(14)	ER Vent 1 SP	FLOOD	18.200f	15.550s	21.910	13.090
(15)	ER Vent 1 PS	FLOOD	18.200f	15.550p	21.910	13.426
(16)	ER Vent 2 SB	FLOOD	33.500f	15.550s	21.910	12.114
(17)	ER Vent 2 PS	FLOOD	25.000f	15.550p	21.910	12.992

Distances in METERS.

Tablica 12. Hidrostatičke karakteristike pri stanju oštećenja 16

HYDROSTATIC PROPERTIES with DAMAGE
Trim: Fwd 10.55/165.00, Heel: Stbd 0.62 deg.

Origin Depth	Displacement Weight (MT)	Center of Buoyancy LCB	TCB	VCB	Effective WPA	LCF	BML	BMT
7.444	22,703.73	79.347f	0.155p	7.372	3700.9	88.676f	389.08	11.760

Distances in METERS.----Specific Gravity = 1.025.---True Free Surface included.

Tablica 13. Detalji stabiliteta za stanje oštećenja 16

RIGHTING ARMS vs HEEL ANGLE with DAMAGE

Total CG: LCG = 78.907f TCG = 0.229p VCG = 14.230

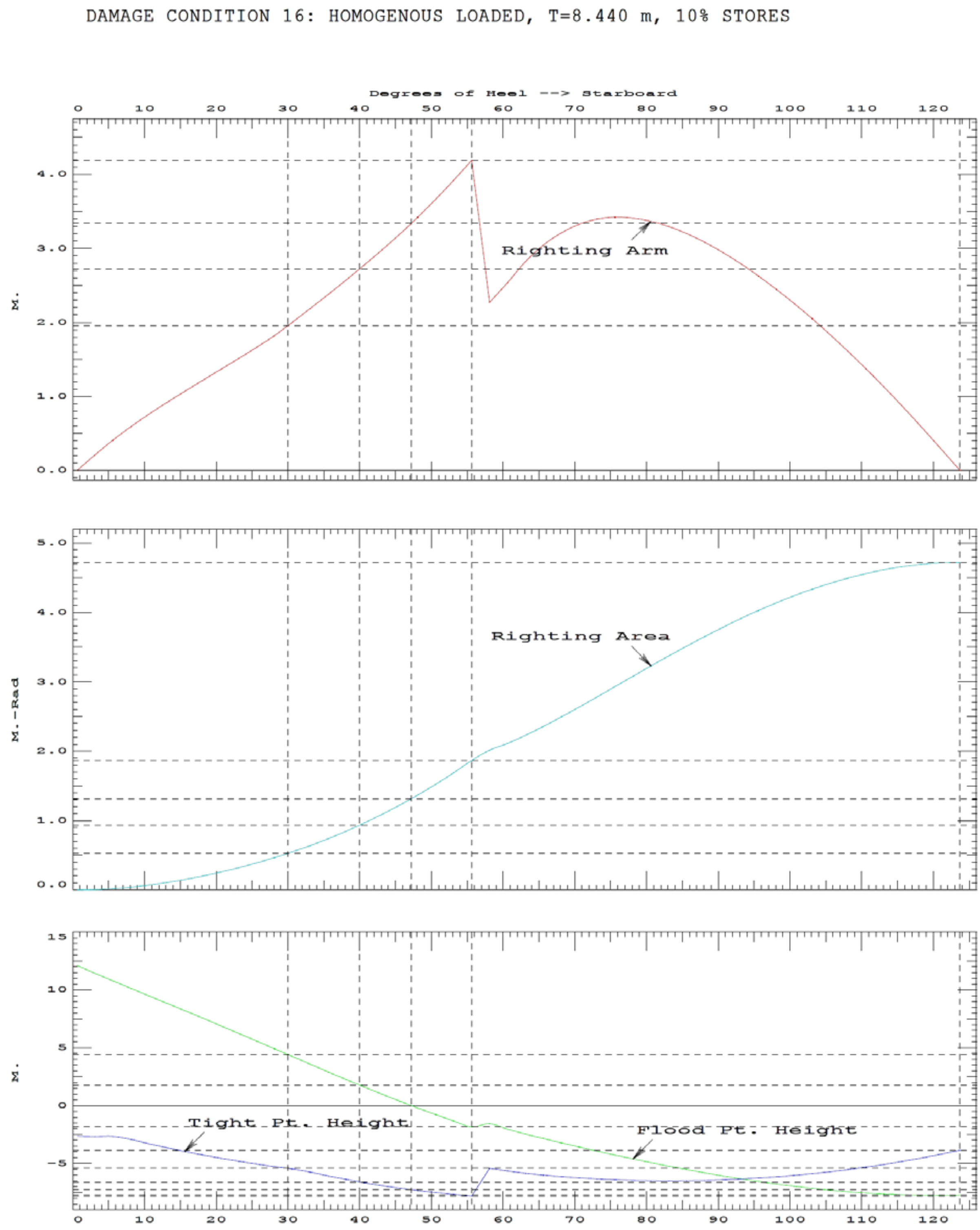
Free Surface Adjustment: 0.024

Adjusted CG: LCG = 78.905f TCG = 0.230p VCG = 14.254

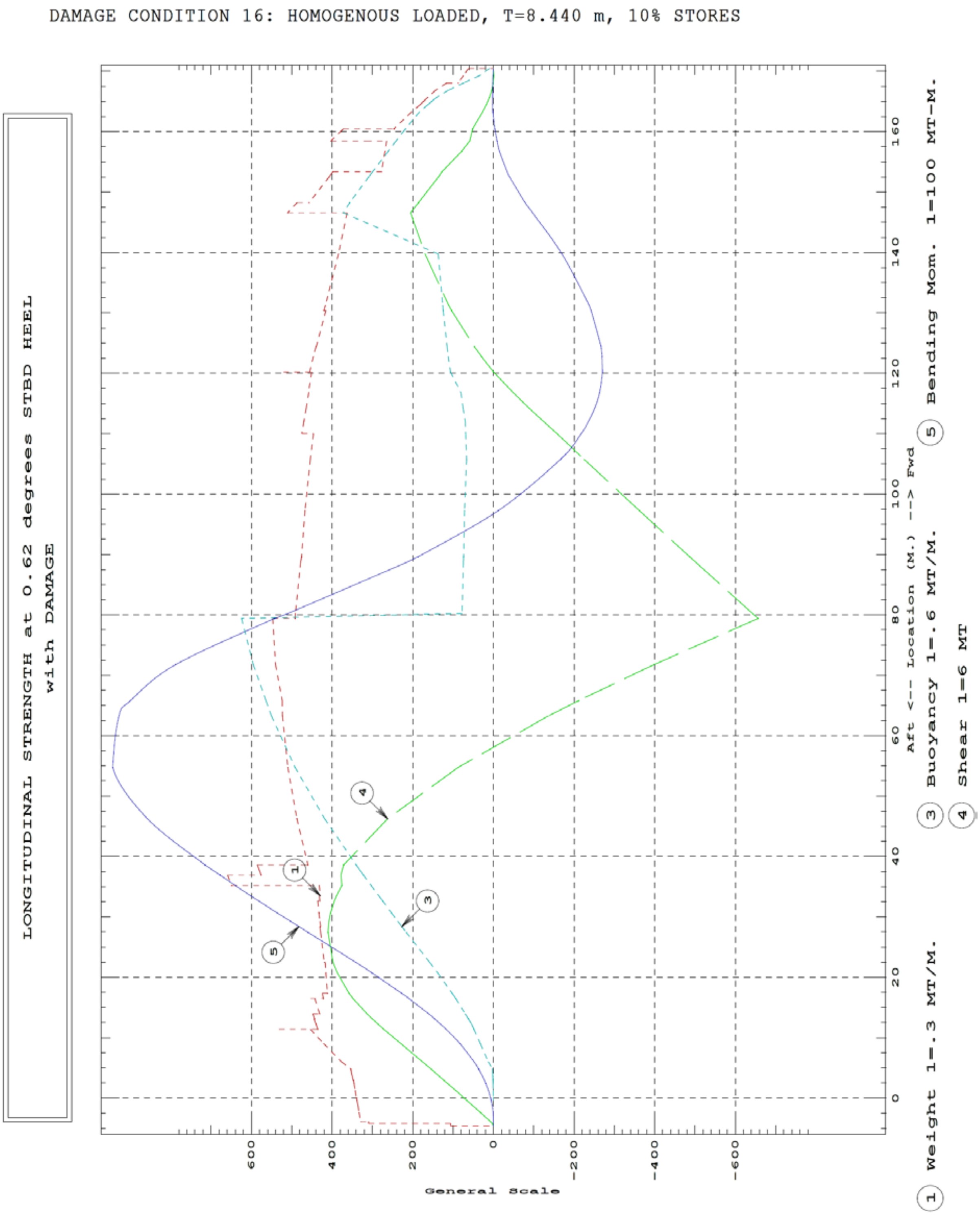
Origin Depth	Degrees of Trim	Degrees of Heel	Displacement Weight (MT)	Righting Arms in Trim	Righting Arms in Heel	Area	Flood Pt Height
7.445	3.66f	0.62s	22,704	0.003a	0.000	0.0000	-2.642(13)
7.409	3.65f	3.12s	22,703	0.000	0.212	0.0046	11.445(16)
7.330	3.64f	5.62s	22,702	0.000	0.412	0.0183	10.786(16)
7.209	3.61f	8.12s	22,702	0.000	0.594	0.0403	10.137(16)
7.053	3.57f	10.62s	22,702	0.000	0.760	0.0699	9.493(16)
6.861	3.53f	13.12s	22,702	0.000	0.918	0.1065	8.853(16)
6.638	3.48f	15.62s	22,701	0.000	1.069	0.1499	8.213(16)
6.396	3.42f	18.12s	22,701	0.000	1.218	0.1998	7.567(16)
6.136	3.35f	20.62s	22,701	0.000	1.365	0.2561	6.912(16)
5.858	3.27f	23.12s	22,701	0.000	1.512	0.3189	6.253(16)
5.563	3.18f	25.62s	22,700	0.000	1.663	0.3881	5.588(16)
5.251	3.09f	28.12s	22,700	0.000	1.823	0.4642	4.919(16)
4.923	2.99f	30.62s	22,700	0.000	2.002	0.5475	4.247(16)
4.575	2.89f	33.12s	22,699	0.000	2.190	0.6389	3.577(16)
4.203	2.78f	35.62s	22,700	0.000	2.379	0.7386	2.914(16)
3.807	2.67f	38.12s	22,699	0.000	2.574	0.8467	2.259(16)
3.386	2.56f	40.62s	22,699	0.000	2.774	0.9633	1.617(16)
2.941	2.45f	43.12s	22,699	0.000	2.980	1.0888	0.988(16)
2.469	2.33f	45.62s	22,699	0.000	3.196	1.2235	0.376(16)
2.158	2.26f	47.19s	22,703	0.003f	3.338	1.3133	0.000(16)
1.969	2.21f	48.12s	22,702	0.000	3.424	1.3679	-0.217(16)
1.434	2.11f	50.62s	22,702	0.000	3.666	1.5226	-0.785(16)
0.861	2.01f	53.12s	22,703	0.000	3.922	1.6882	-1.326(16)
0.246	1.93f	55.62s	22,703	0.000	4.191	1.8651	-1.837(16)
-0.411	0.60f	58.12s	22,703	0.000	2.272	2.0061	-1.571(16)
-1.128	0.62f	60.62s	22,702	0.000	2.539	2.1098	-2.035(16)
-1.889	0.65f	63.12s	22,702	0.000	2.821	2.2267	-2.455(16)
-2.677	0.68f	65.62s	22,702	0.000	3.045	2.3546	-2.841(16)
-3.463	0.71f	68.12s	22,702	0.000	3.210	2.4913	-3.215(16)
-4.242	0.73f	70.62s	22,703	0.000	3.326	2.6341	-3.581(16)
-5.013	0.74f	73.12s	22,703	0.000	3.395	2.7809	-3.937(16)
-5.777	0.75f	75.62s	22,703	0.003a	3.420	2.9296	-4.282(16)
-5.894	0.75f	76.00s	22,703	0.003a	3.421	2.9526	-4.334(16)
-6.533	0.75f	78.12s	22,703	0.000	3.409	3.0787	-4.613(16)
-7.279	0.75f	80.62s	22,704	0.003f	3.366	3.2266	-4.933(16)
-8.010	0.75f	83.12s	22,703	0.003a	3.295	3.3720	-5.241(16)
-8.729	0.74f	85.62s	22,703	0.002a	3.200	3.5138	-5.534(16)
-9.435	0.73f	88.12s	22,703	0.000	3.083	3.6509	-5.813(16)
-10.125	0.71f	90.62s	22,703	0.000	2.947	3.7824	-6.078(16)
-10.797	0.69f	93.12s	22,703	0.000	2.794	3.9077	-6.327(16)
-11.452	0.67f	95.62s	22,703	0.000	2.627	4.0261	-6.560(16)
-12.089	0.65f	98.12s	22,702	0.000	2.446	4.1368	-6.776(16)
-12.707	0.62f	100.62s	22,702	0.000	2.253	4.2393	-6.973(16)
-13.305	0.58f	103.12s	22,702	0.000	2.049	4.3332	-7.151(16)
-13.885	0.55f	105.62s	22,702	0.000	1.834	4.4179	-7.309(16)
-14.444	0.51f	108.12s	22,702	0.000	1.608	4.4930	-7.445(16)
-14.984	0.47f	110.62s	22,702	0.000	1.372	4.5581	-7.558(16)
-15.503	0.42f	113.12s	22,702	0.000	1.127	4.6126	-7.648(16)
-16.003	0.38f	115.62s	22,702	0.000	0.873	4.6562	-7.713(16)
-16.483	0.33f	118.12s	22,702	0.000	0.611	4.6886	-7.751(16)
-16.944	0.28f	120.62s	22,702	0.000	0.341	4.7094	-7.763(16)
-17.384	0.23f	123.12s	22,702	0.000	0.065	4.7183	-7.747(16)
-17.484	0.22f	123.71s	22,703	0.003a	0.000	4.7187	-7.740(16)

Distances in METERS.----Specific Gravity = 1.025.-----------Area in m.-Rad.

Critical Points			LCP	TCP	VCP
(13)	Weath Door Bosuns	TIGHT	157.650f	1.400s	14.910
(16)	ER Vent 2 SB	FLOOD	33.500f	15.550s	21.910



Slika 12. Krivulje stabiliteta za stanje oštećenja 16

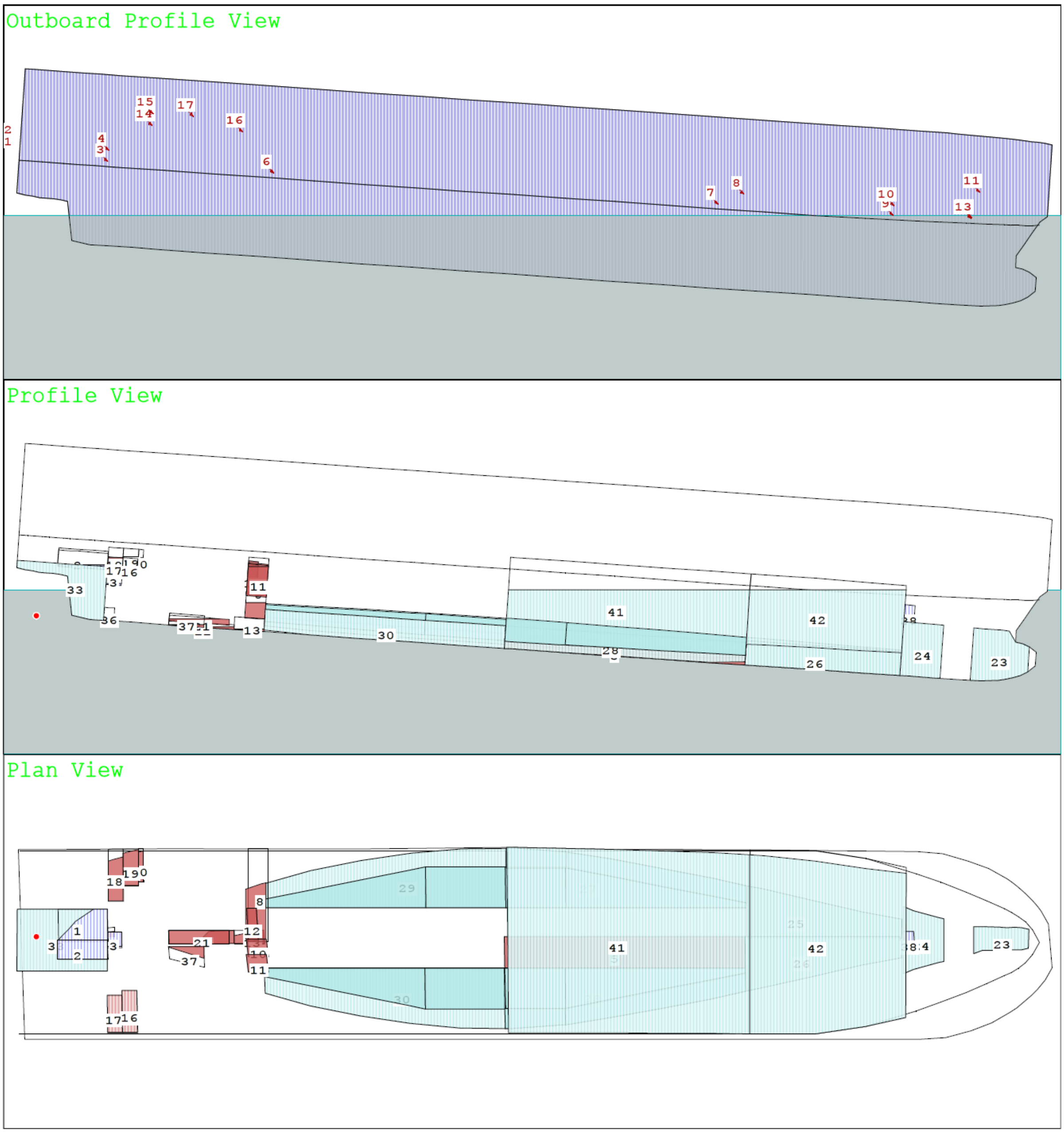


Slika 13. Karakteristike uzdužne čvrstoće za stanje oštećenja 16

6.5. Prikaz proračuna za stanje oštećenja 46

DAMAGE CONDITION 46: HOMOGENOUS LOADED, T=8.440 m, 10% STORES

CG - Draft: 4.370 @ 0.000   Trim: fwd 11.47/165.00   Heel: stbd 3.71 deg.



Slika 14. Grafički prikaz stanja oštećenja 46

Tablica 14. Lista kapaciteta i popis oštećenih tankova pri stanju oštećenja 46

```
                WEIGHT and DISPLACEMENT and CRITICAL POINT STATUS
                         Baseline draft: 4.370 @ Origin
                  Trim: Fwd 11.47/165.00,  Heel: Stbd 3.71 deg.
Part------------------------------Weight(MT)----LCG-----TCG-----VCG
LIGHT SHIP                        12,231.06  76.087f  0.040s 14.838
CREW & EFFECTS                         2.50 128.275f  0.000  29.300
PROVIANT                               2.00 120.625f  0.000  29.200
  Total Fixed--------->           12,235.56  76.105f  0.040s 14.843
                Load-----SpGr-----Weight(MT)----LCG-----TCG-----VCG-------FSM
FW_TANK.P      0.060    1.000          6.54   9.172f  1.913p  8.963      57.5
FW_TANK.S      0.150    1.000          9.73   8.250f  1.702s  9.046      20.4
FW_FEED_TANK.C 0.070    1.000          1.12  12.879f  0.192s  6.276       3.2
HFO_TANK.P     0.210    0.960         61.32  36.959f  3.907p  3.352     189.3
HFO_SETT_1.S   1.000    0.960         42.65  36.900f  1.312s  8.790       0.0
HFO_SETT_2.S   0.950    0.960         40.52  36.913f  3.945s  8.660       4.7
HFO_DAILYTNK.P 1.000    0.960         42.65  36.050f  2.625p  8.790       0.0
HFO_OVERFLOW.C 0.090    0.960          1.94  36.806f  0.170s  0.157       2.8
DO_DAILY_1.S   0.340    0.860         10.13  15.308f 11.012s  9.570      60.8
DO_DAILY_2.S   0.420    0.860         10.09  12.743f 11.849s  9.860      41.6
LO_MECYL_OIL.P 0.370    0.900         15.02  12.738f  9.154p  9.504      64.8
LO_MEOILSTOR.P 0.420    0.900         10.88  15.290f 11.321p  9.783      35.0
LO_AUXOILSTR.P 0.390    0.900          3.00  16.932f 11.700p  9.768       8.1
LO_MEOILCIRC.C 0.760    0.900         12.45  28.336f  0.036s  1.043       5.3
LO_REN_TANK.C  0.140    0.900          2.04  31.593f  0.176s  0.156       4.0
SW_FOREPEAK.C  1.000    1.025        179.29 162.555f  0.000   4.698       0.0
SW_DEEPTANK.C  1.000    1.025        310.36 149.709f  0.000   5.429       0.0
SW_DB_TANK_1.P 1.000    1.025        439.28 130.905f  2.554p  2.437       0.0
SW_DB_TANK_2.P 1.000    1.025        474.28  96.332f  9.180p  2.075       0.0
SW_DB_TANK_3.P 1.000    1.025        516.39  62.041f  9.436p  2.058       0.0
SW_DB_TANK_3.S 1.000    1.025        516.39  62.041f  9.436s  2.058       0.0
SW_AFTERPEAK.C 1.000    1.025        216.70   6.223f  0.000   6.759       0.0
STERN_OIL_DR.C 0.090    0.924          0.73  12.322f  0.072s  0.231       0.8
OIL_DR_TANK.S  0.090    0.924          1.66  26.416f  2.350s  0.340       0.8
SEWAGE_TANK.C  1.000    1.000         15.21 147.400f  0.000  10.380       0.0
  Total Tanks--------->            2,940.37  86.631f  1.927p  3.496     499.2
  Total Weight-------->           15,175.93  78.144f  0.341p 12.645
                                   Displ(MT)----LCB-----TCB-----VCB
HULL                    1.025     30,758.59  94.634f  0.576s  6.398
HFO_DBTANK_2.S Balance  0.960       -378.05  99.703f  2.545s  1.109
SW_DB_TANK_1.S Flooded  1.025       -439.28 130.905f  2.554s  2.437
SW_DB_TANK_2.S Flooded  1.025       -474.28  96.332f  9.180s  2.075
HOLD_2.C       Flooded  1.025     -9,702.86  99.820f  0.659s  7.121
HOLD_1.C       Flooded  1.025     -4,588.15 132.466f  0.630s  9.551
  Total Displacement--> 1.027     15,175.97  78.652f  0.131s  5.364
-----------------------------------------------------------------------------
```

Tablica 15. Popis kritičnih točaka

```
Part-------------------------------------------LRP-----TRP-----VRP
HFO_DBTANK_2.S Balanced at:                      0.000   0.000   0.000
Distances in METERS.---------------------------------------Moments in m.-MT.

       Critical Points----------------------LCP-----TCP-----VCP-----Height
    (1) AirPipe AP SB              TIGHT   9.900a 15.100s 15.260     10.553
    (2) AirPipe AP PS              TIGHT   9.900a 15.100p 15.260     12.501
    (3) AirPipe FreshW SB          TIGHT  11.110f 15.100s 15.260      9.097
    (4) AirPipe FreshW PS          TIGHT  11.110f 15.100p 15.260     11.045
    (5) AirPipe DB 3 SB            TIGHT  39.250f 15.130s 15.260      7.144
    (6) AirPipe DB 3 PS            TIGHT  39.250f 15.130s 15.260      7.144
    (7) AirPipe DB 2 SB            TIGHT 114.680f 14.950s 15.260      1.927
    (8) AirPipe DB 2 PS            TIGHT 118.920f 14.950p 15.260      3.562
    (9) AirPipe DB 1 SB            TIGHT 144.400f 12.060s 15.260      0.053
   (10) AirPipe DB 1 PS            TIGHT 144.400f 12.060p 15.260      1.609
   (11) AirPipe FP                 TIGHT 158.750f 10.150p 18.710      3.926
   (12) Weath Door Domest          TIGHT 157.650f  0.600p 14.910     -0.397
   (13) Weath Door Bosuns          TIGHT 157.650f  1.400s 14.910     -0.526
   (14) ER Vent 1 SP               FLOOD  18.200f 15.550s 21.910     15.197
   (15) ER Vent 1 PS               FLOOD  18.200f 15.550p 21.910     17.203
   (16) ER Vent 2 SB               FLOOD  33.500f 15.550s 21.910     14.136
   (17) ER Vent 2 PS               FLOOD  25.000f 15.550p 21.910     16.731
    Distances in METERS.------------------------------------------------
```

Tablica 16. Hidrostatičke karakteristike pri stanju oštećenja 46

```
                  HYDROSTATIC PROPERTIES with DAMAGE
             Trim: Fwd 11.47/165.00, Heel: Stbd 3.71 deg.

 Origin  Displacement     Center of Buoyancy  Effective
  Depth----Weight(MT)----LCB-----TCB-----VCB-----WPA-----LCF------BML-----BMT
  4.350    15,175.97  78.652f  0.131s  5.364  2220.6  79.027f  315.32   9.005
Distances in METERS.----Specific Gravity = 1.025.---True Free Surface included.
```

Tablica 17. Detalji stabiliteta za stanje oštećenja 46

RIGHTING ARMS vs HEEL ANGLE with DAMAGE

Total CG: LCG = 78.907f TCG = 0.229p VCG = 14.230

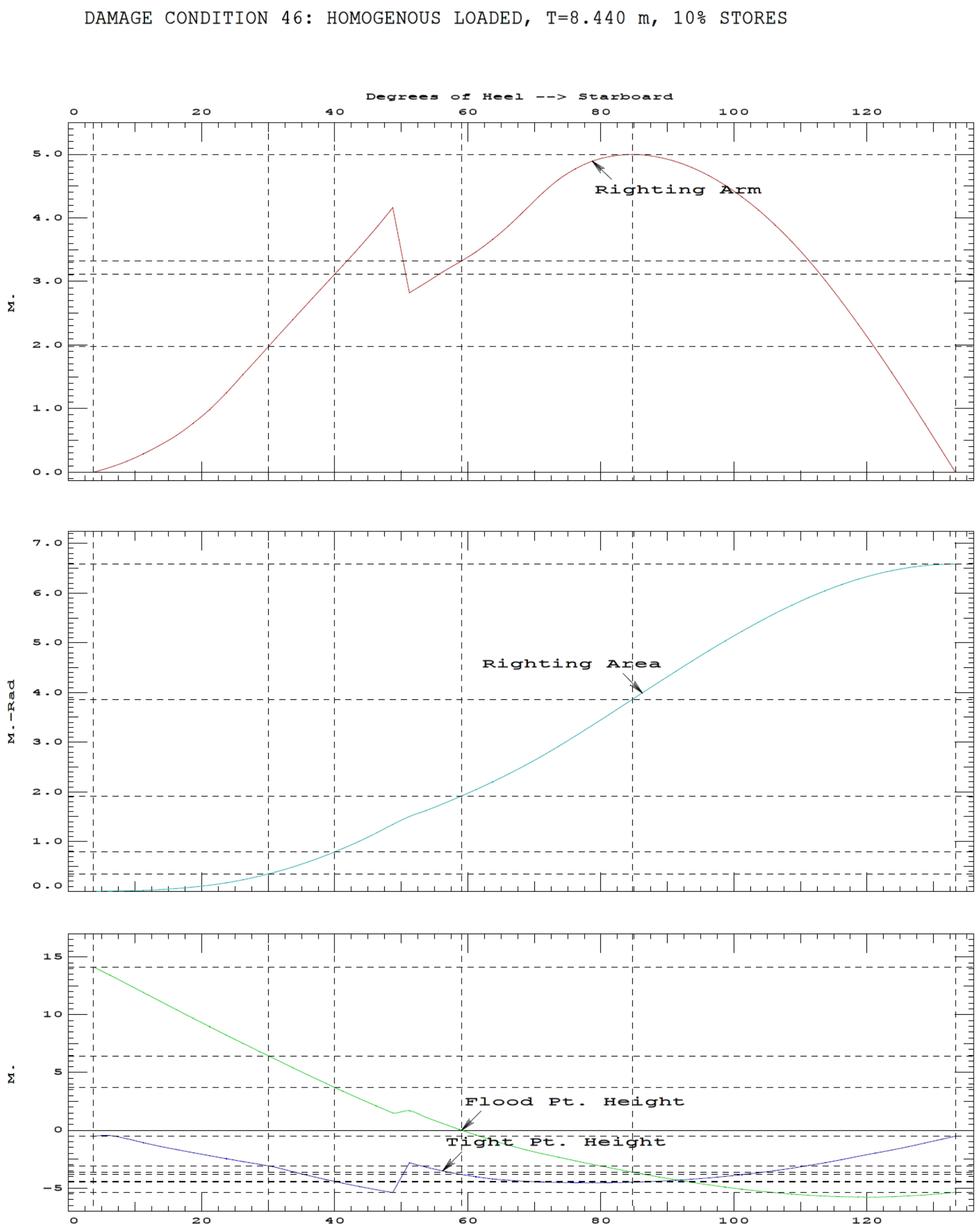
Free Surface Adjustment: 0.024

Adjusted CG: LCG = 78.905f TCG = 0.230p VCG = 14.254

Origin Depth	Degrees of Trim	Degrees of Heel	Displacement Weight (MT)	Righting Arms in Trim	Righting Arms in Heel	Area	Flood Pt Height
7.445	3.66f	0.62s	22,704	0.003a	0.000	0.0000	-2.642(13)
7.409	3.65f	3.12s	22,703	0.000	0.212	0.0046	11.445(16)
7.330	3.64f	5.62s	22,702	0.000	0.412	0.0183	10.786(16)
7.209	3.61f	8.12s	22,702	0.000	0.594	0.0403	10.137(16)
7.053	3.57f	10.62s	22,702	0.000	0.760	0.0699	9.493(16)
6.861	3.53f	13.12s	22,702	0.000	0.918	0.1065	8.853(16)
6.638	3.48f	15.62s	22,701	0.000	1.069	0.1499	8.213(16)
6.396	3.42f	18.12s	22,701	0.000	1.218	0.1998	7.567(16)
6.136	3.35f	20.62s	22,701	0.000	1.365	0.2561	6.912(16)
5.858	3.27f	23.12s	22,701	0.000	1.512	0.3189	6.253(16)
5.563	3.18f	25.62s	22,700	0.000	1.663	0.3881	5.588(16)
5.251	3.09f	28.12s	22,700	0.000	1.823	0.4642	4.919(16)
4.923	2.99f	30.62s	22,700	0.000	2.002	0.5475	4.247(16)
4.575	2.89f	33.12s	22,699	0.000	2.190	0.6389	3.577(16)
4.203	2.78f	35.62s	22,700	0.000	2.379	0.7386	2.914(16)
3.807	2.67f	38.12s	22,699	0.000	2.574	0.8467	2.259(16)
3.386	2.56f	40.62s	22,699	0.000	2.774	0.9633	1.617(16)
2.941	2.45f	43.12s	22,699	0.000	2.980	1.0888	0.988(16)
2.469	2.33f	45.62s	22,699	0.000	3.196	1.2235	0.376(16)
2.158	2.26f	47.19s	22,703	0.003f	3.338	1.3133	0.000(16)
1.969	2.21f	48.12s	22,702	0.000	3.424	1.3679	-0.217(16)
1.434	2.11f	50.62s	22,702	0.000	3.666	1.5226	-0.785(16)
0.861	2.01f	53.12s	22,703	0.000	3.922	1.6882	-1.326(16)
0.246	1.93f	55.62s	22,703	0.000	4.191	1.8651	-1.837(16)
-0.411	0.60f	58.12s	22,703	0.000	2.272	2.0061	-1.571(16)
-1.128	0.62f	60.62s	22,702	0.000	2.539	2.1098	-2.035(16)
-1.889	0.65f	63.12s	22,702	0.000	2.821	2.2267	-2.455(16)
-2.677	0.68f	65.62s	22,702	0.000	3.045	2.3546	-2.841(16)
-3.463	0.71f	68.12s	22,702	0.000	3.210	2.4913	-3.215(16)
-4.242	0.73f	70.62s	22,703	0.000	3.326	2.6341	-3.581(16)
-5.013	0.74f	73.12s	22,703	0.000	3.395	2.7809	-3.937(16)
-5.777	0.75f	75.62s	22,703	0.003a	3.420	2.9296	-4.282(16)
-5.894	0.75f	76.00s	22,703	0.003a	3.421	2.9526	-4.334(16)
-6.533	0.75f	78.12s	22,703	0.000	3.409	3.0787	-4.613(16)
-7.279	0.75f	80.62s	22,704	0.003f	3.366	3.2266	-4.933(16)
-8.010	0.75f	83.12s	22,703	0.003a	3.295	3.3720	-5.241(16)
-8.729	0.74f	85.62s	22,703	0.002a	3.200	3.5138	-5.534(16)
-9.435	0.73f	88.12s	22,703	0.000	3.083	3.6509	-5.813(16)
-10.125	0.71f	90.62s	22,703	0.000	2.947	3.7824	-6.078(16)
-10.797	0.69f	93.12s	22,703	0.000	2.794	3.9077	-6.327(16)
-11.452	0.67f	95.62s	22,703	0.000	2.627	4.0261	-6.560(16)
-12.089	0.65f	98.12s	22,702	0.000	2.446	4.1368	-6.776(16)
-12.707	0.62f	100.62s	22,702	0.000	2.253	4.2393	-6.973(16)
-13.305	0.58f	103.12s	22,702	0.000	2.049	4.3332	-7.151(16)
-13.885	0.55f	105.62s	22,702	0.000	1.834	4.4179	-7.309(16)
-14.444	0.51f	108.12s	22,702	0.000	1.608	4.4930	-7.445(16)
-14.984	0.47f	110.62s	22,702	0.000	1.372	4.5581	-7.558(16)
-15.503	0.42f	113.12s	22,702	0.000	1.127	4.6126	-7.648(16)
-16.003	0.38f	115.62s	22,702	0.000	0.873	4.6562	-7.713(16)
-16.483	0.33f	118.12s	22,702	0.000	0.611	4.6886	-7.751(16)
-16.944	0.28f	120.62s	22,702	0.000	0.341	4.7094	-7.763(16)
-17.384	0.23f	123.12s	22,702	0.000	0.065	4.7183	-7.747(16)
-17.484	0.22f	123.71s	22,703	0.003a	0.000	4.7187	-7.740(16)

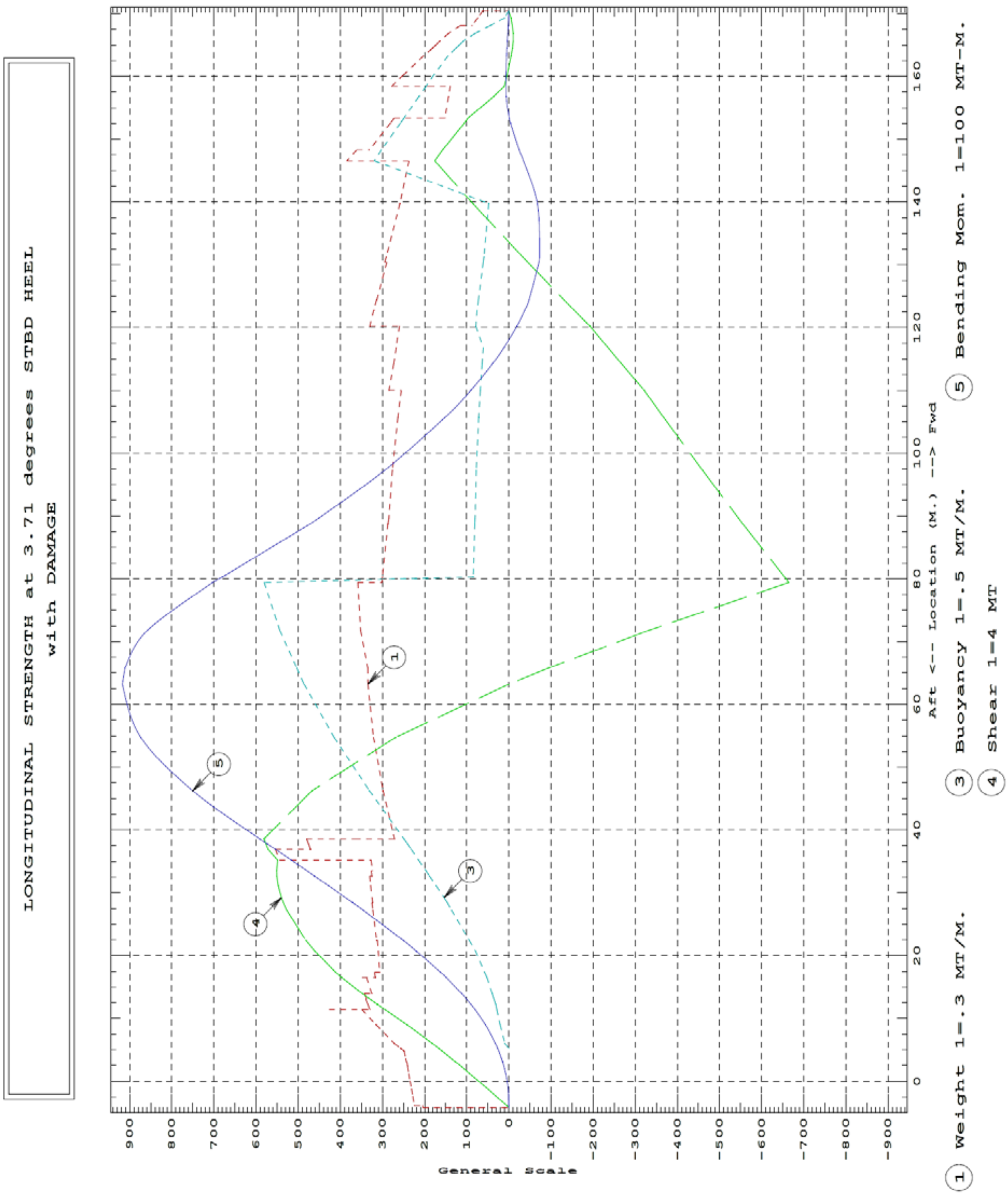
Distances in METERS.----Specific Gravity = 1.025.-----------Area in m.-Rad.

Critical Points			LCP	TCP	VCP
(13)	Weath Door Bosuns	TIGHT	157.650f	1.400s	14.910
(16)	ER Vent 2 SB	FLOOD	33.500f	15.550s	21.910



Slika 15. Krivulje stabiliteta za stanje oštećenja 46

DAMAGE CONDITION 46: HOMOGENOUS LOADED, T=8.440 m, 10% STORES



Slika 16. Karakteristike uzdužne čvrstoće za stanje oštećenja 46

6.6. Rezultati determinističkog proračuna

Slijedećim tablicama prikazani su ukupni rezultati za svih 54 stanja oštećenja. Oni su uspoređivani sa kriterijima stabiliteta broda u oštećenom stanju. Svakom stanju je opisano koji prostori su naplavljeni, koji kriterij je primijenjen, te postignuti iznosi dobiveni proračunom. Također je prikazan i najveći moment svijanja za svako stanje. Sva stanja oštećenja zadovoljavaju zadane kriterije stabiliteta u oštećenom stanju. Uz zadovoljavanje kriterija, postoji i druga razina zadovoljenja, jer su volumeni naplavljenih prostora bili mnogo veće nego li je to predviđeno u pravilima [9].

Prikazani su sljedeći rezultati:

- [Tablica 18., Tablica 19. i Tablica 20.] Tablični rezultati determinističkog proračuna za LC 1 – homogeno stanje sa 10% zaliha.
- [Tablica 21., Tablica 22. i Tablica 23.] Tablični rezultati determinističkog proračuna za LC 2 – balastno stanje sa 10% zaliha.
- [Slika 17. i Slika 18.] Prikaz najvećih momenata savijanja za LC 1 i LC 2.
- [Slika 19. i Slika 20.] Prikaz najvećih smičnih sila za LC 1 i LC 2.
- [Slika 21. i Slika 22.] Prikaz uzdužnog položaja najvećih momenata savijanja za LC 1 i LC 2.
- [Slika 23. i Slika 24.] Prikaz uzdužnog položaja najvećih smičnih sila za LC 1 i LC 2.
- [Slika 25.] Prikaz visinskog položaja težišta mase broda za svaki slučaj oštećenja.
- [Slika 26.] Prikaz krivulje MAXVCG za LC 1.

Tablica 18. Rezultati proračuna stabiliteta i uzdužne čvrstoće (Stanja oštećenja 1 - 9)

STANJE	NAPLAVLJENI DIVISION	KRITERIJI STABILITETA		POSTIGNUTO	NAJVEĆI MOMENT SAVIJANJA (t-m)
STANJE OŠTEĆENJA 1, HOMOGENO NATOVAREN BROD SA 10% ZALIHA	Division 1 bez:	**Kriteriji stabiliteta u oštećenom stanju**			130880
	hold_4.c	(1) Kut ravnoteže	< 25°	5,06°	
	steering.c	(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	122,91°	
	strojarnica.c	(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	3,722	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	4,1013	
STANJE OŠTEĆENJA 2, HOMOGENO NATOVAREN BROD SA 10% ZALIHA	Division 1	**Kriteriji stabiliteta u oštećenom stanju**			152306
		(1) Kut ravnoteže	< 25°	8,03°	
		(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	119,97°	
		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	3,724	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	4,1452	
STANJE OŠTEĆENJA 3, HOMOGENO NATOVAREN BROD SA 10% ZALIHA	Division 2 bez:	**Kriteriji stabiliteta u oštećenom stanju**			122567
	hold_3.c	(1) Kut ravnoteže	< 25°	3,80°	
		(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	121,48°	
		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	3,534	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	3,8903	
STANJE OŠTEĆENJA 4, HOMOGENO NATOVAREN BROD SA 10% ZALIHA	Division 2	**Kriteriji stabiliteta u oštećenom stanju**			68124
		(1) Kut ravnoteže	< 25°	1,41°	
		(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	124,18°	
		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	4,367	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	4,3998	
STANJE OŠTEĆENJA 5, HOMOGENO NATOVAREN BROD SA 10% ZALIHA	Division 3 bez:	**Kriteriji stabiliteta u oštećenom stanju**			127010
	hold_2.c	(1) Kut ravnoteže	< 25°	3,41°	
		(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	122,32°	
		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	3,622	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	4,0253	
STANJE OŠTEĆENJA 6, HOMOGENO NATOVAREN BROD SA 10% ZALIHA	Division 3	**Kriteriji stabiliteta u oštećenom stanju**			84483
		(1) Kut ravnoteže	< 25°	2,80°	
		(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	122,93°	
		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	3,800	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	4,3443	
STANJE OŠTEĆENJA 7, HOMOGENO NATOVAREN BROD SA 10% ZALIHA	Division 4 bez:	**Kriteriji stabiliteta u oštećenom stanju**			129557
	hold_1.c	(1) Kut ravnoteže	< 25°	1,02°	
		(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	125,50°	
		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	3,614	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	3,9710	
STANJE OŠTEĆENJA 8, HOMOGENO NATOVAREN BROD SA 10% ZALIHA	Division 4	**Kriteriji stabiliteta u oštećenom stanju**			154540
		(1) Kut ravnoteže	< 25°	3,58°	
		(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	122,96°	
		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	3,617	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	3,9890	
STANJE OŠTEĆENJA 9, HOMOGENO NATOVAREN BROD SA 10% ZALIHA	Division 5	**Kriteriji stabiliteta u oštećenom stanju**			132208
		(1) Kut ravnoteže	< 25°	1,07°	
		(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	126,44°	
		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	3,701	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	4,0749	

Tablica 19. Rezultati proračuna stabiliteta i uzdužne čvrstoće (Oštećena stanja 10 – 18)

STANJE	NAPLAVLJENI DIVISION	KRITERIJI STABILITETA		POSTIGNUTO	NAJVEĆI MOMENT SAVIJANJA (t-m)
STANJE OŠTEĆENJA 10, HOMOGENO NATOVAREN BROD SA 10% ZALIHA	Division 6	**Kriteriji stabiliteta u oštećenom stanju**			129366
		(1) Kut ravnoteže	< 25°	1,02°	
		(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	126,86°	
		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	3,743	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	4,1175	
STANJE OŠTEĆENJA 11, HOMOGENO NATOVAREN BROD SA 10% ZALIHA	Divisioni 1 i 2 bez:	**Kriteriji stabiliteta u oštećenom stanju**			127982
	hold_4.c	(1) Kut ravnoteže	< 25°	5,40°	
	steering.c	(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	119,66°	
	strojarnica.c	(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	3,510	
	hold_3.c	(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	3,9132	
STANJE OŠTEĆENJA 12, HOMOGENO NATOVAREN BROD SA 10% ZALIHA	Divisioni 1 i 2	**Kriteriji stabiliteta u oštećenom stanju**			88449
		(1) Kut ravnoteže	< 25°	3,13°	
		(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	121,91°	
		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	5,628	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	5,3922	
STANJE OŠTEĆENJA 13, HOMOGENO NATOVAREN BROD SA 10% ZALIHA	Divisioni 2 i 3 bez:	**Kriteriji stabiliteta u oštećenom stanju**			123797
	hold_3.c	(1) Kut ravnoteže	< 25°	4,20°	
	hold_2.c	(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	118,62°	
		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	3,410	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	3,8643	
STANJE OŠTEĆENJA 14, HOMOGENO NATOVAREN BROD SA 10% ZALIHA	Divisioni 2 i 3	**Kriteriji stabiliteta u oštećenom stanju**			-129855
		(1) Kut ravnoteže	< 25°	0,68°	
		(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	122,12°	
		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	6,212	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	5,6673	
STANJE OŠTEĆENJA 15, HOMOGENO NATOVAREN BROD SA 10% ZALIHA	Divisioni 3 i 4 bez:	**Kriteriji stabiliteta u oštećenom stanju**			127009
	hold_1.c	(1) Kut ravnoteže	< 25°	3,41°	
	hold_2.c	(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	120,30°	
		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	3,421	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	3,7997	
STANJE OŠTEĆENJA 16, HOMOGENO NATOVAREN BROD SA 10% ZALIHA	Divisioni 3 i 4	**Kriteriji stabiliteta u oštećenom stanju**			94374
		(1) Kut ravnoteže	< 25°	0,62°	
		(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	123,09°	
		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	4,191	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	4,7187	
STANJE OŠTEĆENJA 17, HOMOGENO NATOVAREN BROD SA 10% ZALIHA	Divisioni 4 i 5 bez:	**Kriteriji stabiliteta u oštećenom stanju**			132210
	hold_1.c	(1) Kut ravnoteže	< 25°	1,07°	
		(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	124,44°	
		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	3,501	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	3,8451	
STANJE OŠTEĆENJA 18, HOMOGENO NATOVAREN BROD SA 10% ZALIHA	Divisioni 4 i 5	**Kriteriji stabiliteta u oštećenom stanju**			162193
		(1) Kut ravnoteže	< 25°	3,79°	
		(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	121,74°	
		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	3,504	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	3,8913	

Tablica 20. Rezultati proračuna stabiliteta i uzdužne čvrstoće (Oštećena stanja 19 – 27)

STANJE	NAPLAVLJENI DIVISION	KRITERIJI STABILITETA		POSTIGNUTO	NAJVEĆI MOMENT SAVIJANJA (t-m)
	Divisioni 5 i 6	**Kriteriji stabiliteta u oštećenom stanju**			
STANJE OŠTEĆENJA 19,		(1) Kut ravnoteže	< 25°	1,07°	
HOMOGENO NATOVAREN		(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	125,82°	132065
BROD SA 10% ZALIHA		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	3,634	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	3,9923	
	Divisioni 1, 2 i 3 bez:	**Kriteriji stabiliteta u oštećenom stanju**			
STANJE OŠTEĆENJA 20,	hold_4.c	(1) Kut ravnoteže	< 25°	6,10°	
HOMOGENO NATOVAREN	steering.c	(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	116,12°	125468
BROD SA 10% ZALIHA	strojarnica.c	(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	3,310	
	hold_3.c	(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	3,7562	
	hold_2.c				
	Divisioni 1, 2 i 3	**Kriteriji stabiliteta u oštećenom stanju**			
STANJE OŠTEĆENJA 21,		(1) Kut ravnoteže	< 25°	1,31°	
HOMOGENO NATOVAREN		(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	120,87°	-66767
BROD SA 10% ZALIHA		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	7,598	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	7,3019	
	Divisioni 2, 3 i 4 bez:	**Kriteriji stabiliteta u oštećenom stanju**			
STANJE OŠTEĆENJA 21,	hold_3.c	(1) Kut ravnoteže	< 25°	4,21°	
HOMOGENO NATOVAREN	hold_2.c	(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	116,51°	123788
BROD SA 10% ZALIHA	hold_1.c	(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	3,200	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	3,6412	
	Divisioni 2, 3 i 4	**Kriteriji stabiliteta u oštećenom stanju**			
STANJE OŠTEĆENJA 23,		(1) Kut ravnoteže	< 25°	6,11°	
HOMOGENO NATOVAREN		(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	116,12°	125468
BROD SA 10% ZALIHA		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	3,310	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	3,7563	
	Divisioni 3, 4 i 5 bez:	**Kriteriji stabiliteta u oštećenom stanju**			
STANJE OŠTEĆENJA 24,	hold_2.c	(1) Kut ravnoteže	< 25°	3,56°	
HOMOGENO NATOVAREN	hold_1.c	(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	119,10°	130245
BROD SA 10% ZALIHA		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	3,301	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	3,6772	
	Divisioni 3, 4 i 5	**Kriteriji stabiliteta u oštećenom stanju**			
STANJE OŠTEĆENJA 25,		(1) Kut ravnoteže	< 25°	0,41°	
HOMOGENO NATOVAREN		(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	120,29°	-104686
BROD SA 10% ZALIHA		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	6,875	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	6,6164	
	Divisioni 4, 5 i 6 bez:	**Kriteriji stabiliteta u oštećenom stanju**			
STANJE OŠTEĆENJA 26,	hold_1.c	(1) Kut ravnoteže	< 25°	1,07°	
HOMOGENO NATOVAREN		(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	123,80°	132054
BROD SA 10% ZALIHA		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	3,430	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	3,7626	
	Divisioni 4, 5 i 6	**Kriteriji stabiliteta u oštećenom stanju**			
STANJE OŠTEĆENJA 27,		(1) Kut ravnoteže	< 25°	3,90°	
HOMOGENO NATOVAREN		(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	120,99°	165563
BROD SA 10% ZALIHA		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	3,432	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	3,8183	

Tablica 21. Rezultati proračuna stabiliteta i uzdužne čvrstoće (Oštećena stanja 31 – 39)

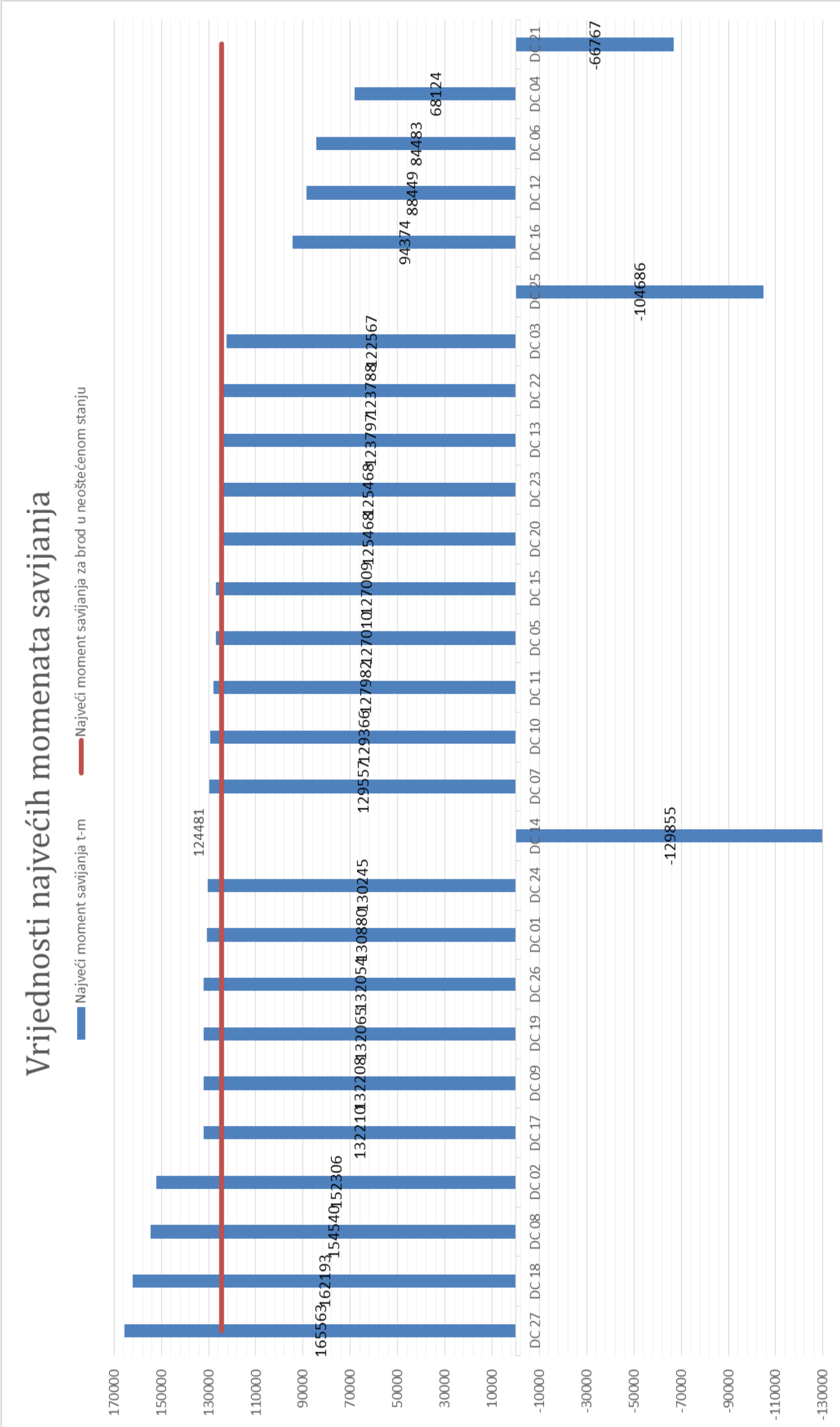
STANJE	NAPLAVLJENI DIVISION	KRITERIJI STABILITETA		POSTIGNUTO	NAJVEĆI MOMENT SAVIJANJA (t-m)
STANJE OŠTEĆENJA 31, BALASTNO NATOVAREN BROD SA 10% ZALIHA	Division 1 bez:	**Kriteriji stabiliteta u oštećenom stanju**			128094
	hold_4.c	(1) Kut ravnoteže	< 25°	0,98°	
	steering.c	(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	136,01°	
	strojarnica.c	(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	5,460	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	7,0785	
STANJE OŠTEĆENJA 32, BALASTNO NATOVAREN BROD SA 10% ZALIHA	Division 1	**Kriteriji stabiliteta u oštećenom stanju**			152306
		(1) Kut ravnoteže	< 25°	1,74°	
		(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	135,26°	
		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	5,461	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	7,0636	
STANJE OŠTEĆENJA 33, BALASTNO NATOVAREN BROD SA 10% ZALIHA	Division 2 bez:	**Kriteriji stabiliteta u oštećenom stanju**			107242
	hold_3.c	(1) Kut ravnoteže	< 25°	1,53°	
		(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	133,20°	
		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	5,254	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	6,8696	
STANJE OŠTEĆENJA 34, BALASTNO NATOVAREN BROD SA 10% ZALIHA	Division 2	**Kriteriji stabiliteta u oštećenom stanju**			73278
		(1) Kut ravnoteže	< 25°	1,17°	
		(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	133,56°	
		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	5,254	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	6,8860	
STANJE OŠTEĆENJA 35, BALASTNO NATOVAREN BROD SA 10% ZALIHA	Division 3 bez:	**Kriteriji stabiliteta u oštećenom stanju**			106576
	hold_2.c	(1) Kut ravnoteže	< 25°	1,54°	
		(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	133,39°	
		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	5,274	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	6,8751	
STANJE OŠTEĆENJA 36, BALASTNO NATOVAREN BROD SA 10% ZALIHA	Division 3	**Kriteriji stabiliteta u oštećenom stanju**			83197
		(1) Kut ravnoteže	< 25°	8,19°	
		(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	126,78°	
		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	5,283	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	6,6166	
STANJE OŠTEĆENJA 37, BALASTNO NATOVAREN BROD SA 10% ZALIHA	Division 4 bez:	**Kriteriji stabiliteta u oštećenom stanju**			108556
	hold_1.c	(1) Kut ravnoteže	< 25°	0,36°	
		(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	135,54°	
		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	5,282	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	6,8446	
STANJE OŠTEĆENJA 38, BALASTNO NATOVAREN BROD SA 10% ZALIHA	Division 4	**Kriteriji stabiliteta u oštećenom stanju**			118711
		(1) Kut ravnoteže	< 25°	0,41°	
		(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	135,50°	
		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	5,252	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	6,7515	
STANJE OŠTEĆENJA 39, BALASTNO NATOVAREN BROD SA 10% ZALIHA	Division 5	**Kriteriji stabiliteta u oštećenom stanju**			107334
		(1) Kut ravnoteže	< 25°	0,36°	
		(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	136,46°	
		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	5,411	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	7,0155	

Tablica 22. Rezultati proračuna stabiliteta i uzdužne čvrstoće (Oštećena stanja 40 – 48)

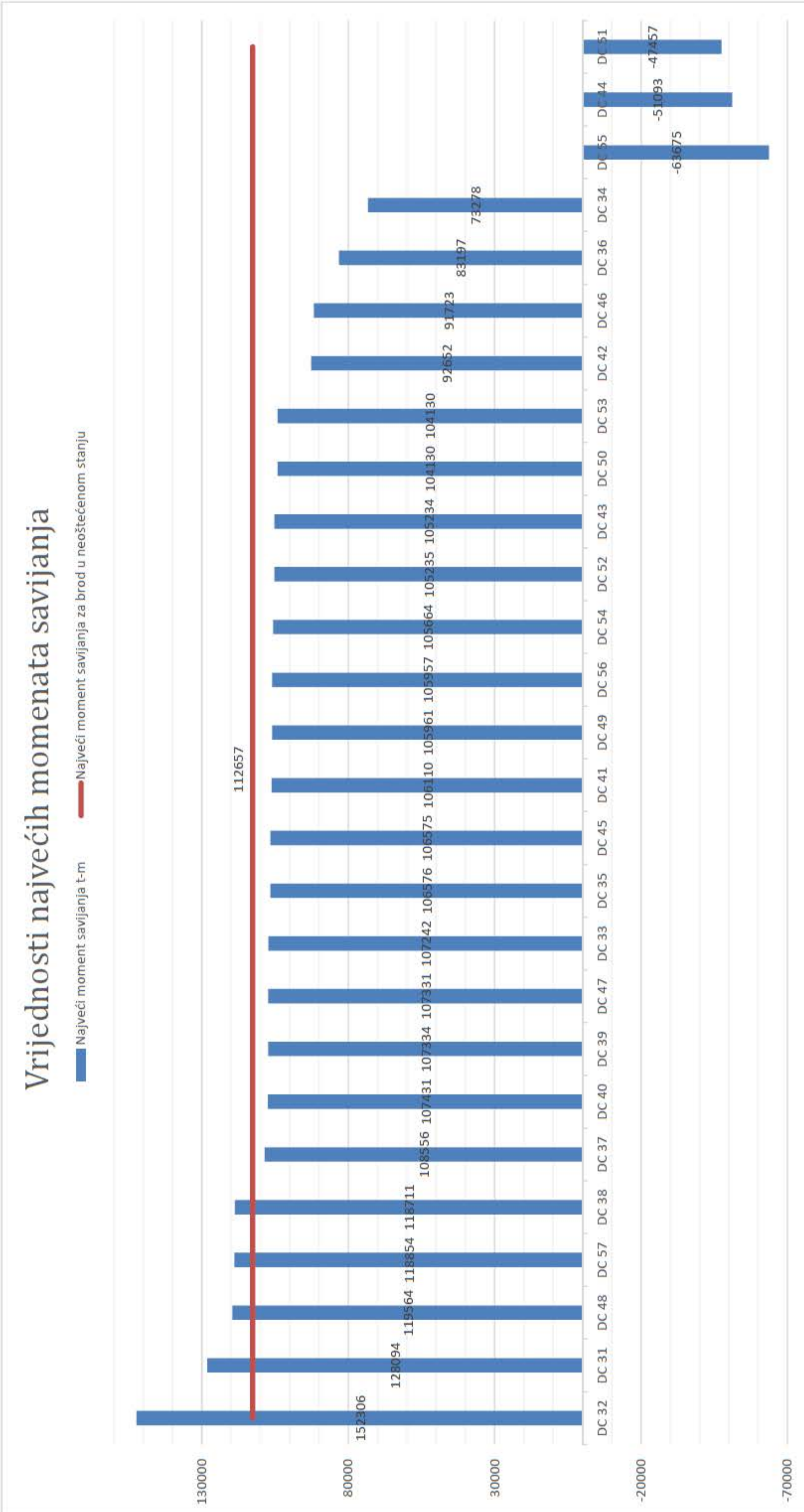
STANJE	NAPLAVLJENI DIVISION	KRITERIJI STABILITETA		POSTIGNUTO	NAJVEĆI MOMENT SAVIJANJA (t-m)
STANJE OŠTEĆENJA 40, BALASTNO NATOVAREN BROD SA 10% ZALIHA	Division 6	**Kriteriji stabiliteta u oštećenom stanju**			107431
		(1) Kut ravnoteže	< 25°	0,36°	
		(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	136,71°	
		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	5,460	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	7,0795	
STANJE OŠTEĆENJA 41, BALASTNO NATOVAREN BROD SA 10% ZALIHA	Divisioni 1 i 2 bez:	**Kriteriji stabiliteta u oštećenom stanju**			106110
	hold_4.c	(1) Kut ravnoteže	< 25°	2,13°	
	steering.c	(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	132,05°	
	strojarnica.c	(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	5,159	
	hold_3.c	(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	6,7497	
STANJE OŠTEĆENJA 42, BALASTNO NATOVAREN BROD SA 10% ZALIHA	Divisioni 1 i 2	**Kriteriji stabiliteta u oštećenom stanju**			92652
		(1) Kut ravnoteže	< 25°	5,65°	
		(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	128,56°	
		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	6,248	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	7,4691	
STANJE OŠTEĆENJA 43, BALASTNO NATOVAREN BROD SA 10% ZALIHA	Divisioni 2 i 3 bez:	**Kriteriji stabiliteta u oštećenom stanju**			105234
	hold_3.c	(1) Kut ravnoteže	< 25°	2,51°	
	hold_2.c	(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	129,58°	
		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	4,965	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	6,5277	
STANJE OŠTEĆENJA 44, BALASTNO NATOVAREN BROD SA 10% ZALIHA	Divisioni 2 i 3	**Kriteriji stabiliteta u oštećenom stanju**			-51093
		(1) Kut ravnoteže	< 25°	1,81°	
		(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	130,28°	
		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	6,705	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	7,1607	
STANJE OŠTEĆENJA 45, BALASTNO NATOVAREN BROD SA 10% ZALIHA	Divisioni 3 i 4 bez:	**Kriteriji stabiliteta u oštećenom stanju**			106575
	hold_1.c	(1) Kut ravnoteže	< 25°	1,55°	
	hold_2.c	(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	131,71°	
		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	4,994	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	6,5183	
STANJE OŠTEĆENJA 46, BALASTNO NATOVAREN BROD SA 10% ZALIHA	Divisioni 3 i 4	**Kriteriji stabiliteta u oštećenom stanju**			91723
		(1) Kut ravnoteže	< 25°	3,71°	
		(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	129,57°	
		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	4,999	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	6,5831	
STANJE OŠTEĆENJA 47, BALASTNO NATOVAREN BROD SA 10% ZALIHA	Divisioni 4 i 5 bez:	**Kriteriji stabiliteta u oštećenom stanju**			107331
	hold_1.c	(1) Kut ravnoteže	< 25°	0,37°	
		(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	134,82°	
		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	5,138	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	6,6623	
STANJE OŠTEĆENJA 48, BALASTNO NATOVAREN BROD SA 10% ZALIHA	Divisioni 4 i 5	**Kriteriji stabiliteta u oštećenom stanju**			119564
		(1) Kut ravnoteže	< 25°	0,41°	
		(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	134,78°	
		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	5,138	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	6,5684	

Tablica 23. Rezultati proračuna stabiliteta i uzdužne čvrstoće (Oštećena stanja 49 – 57)

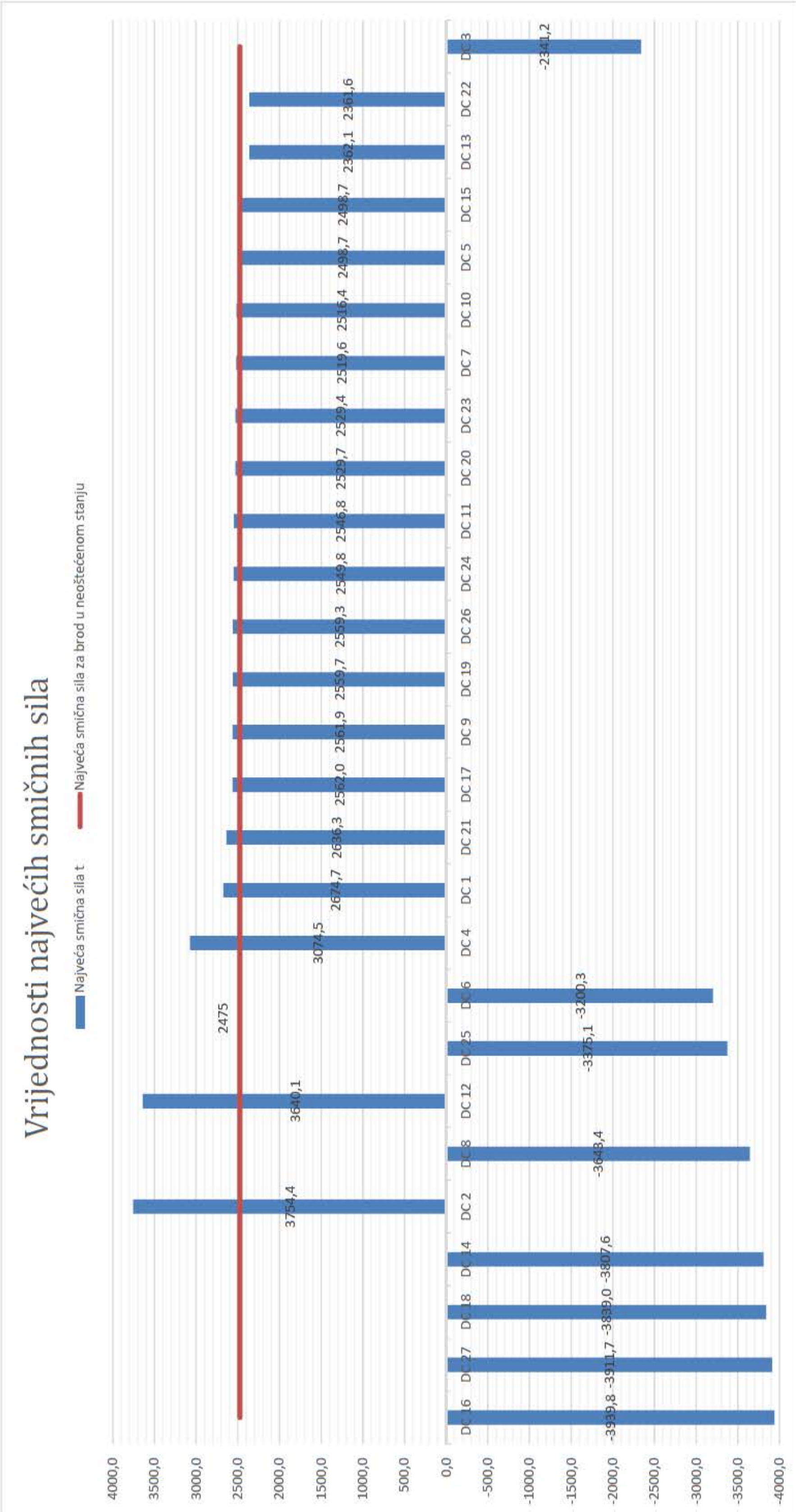
STANJE	NAPLAVLJENI DIVISION	KRITERIJI STABILITETA		POSTIGNUTO	NAJVEĆI MOMENT SAVIJANJA (t-m)
STANJE OŠTEĆENJA 49, BALASTNO NATOVAREN BROD SA 10% ZALIHA	Divisioni 5 i 6	**Kriteriji stabiliteta u oštećenom stanju**			105961
		(1) Kut ravnoteže	< 25°	0,36°	
		(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	136,02°	
		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	5,323	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	6,8915	
STANJE OŠTEĆENJA 50, BALASTNO NATOVAREN BROD SA 10% ZALIHA	Divisioni 1, 2 i 3 bez:	**Kriteriji stabiliteta u oštećenom stanju**			104130
	hold_4.c	(1) Kut ravnoteže	< 25°	3,07°	
	steering.c	(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	128,44°	
	strojarnica.c	(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	4,858	
	hold_3.c	(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	6,4013	
	hold_2.c				
STANJE OŠTEĆENJA 51, BALASTNO NATOVAREN BROD SA 10% ZALIHA	Divisioni 1, 2 i 3	**Kriteriji stabiliteta u oštećenom stanju**			-47457
		(1) Kut ravnoteže	< 25°	2,22°	
		(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	129,29°	
		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	9,248	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	8,7663	
STANJE OŠTEĆENJA 52, BALASTNO NATOVAREN BROD SA 10% ZALIHA	Divisioni 2, 3 i 4 bez:	**Kriteriji stabiliteta u oštećenom stanju**			105235
	hold_3.c	(1) Kut ravnoteže	< 25°	2,50°	
	hold_2.c	(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	127,81°	
	hold_1.c	(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	4,664	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	6,2016	
STANJE OŠTEĆENJA 53, BALASTNO NATOVAREN BROD SA 10% ZALIHA	Divisioni 2, 3 i 4	**Kriteriji stabiliteta u oštećenom stanju**			104130
		(1) Kut ravnoteže	< 25°	3,07°	
		(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	128,44°	
		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	4,858	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	6,4013	
STANJE OŠTEĆENJA 54, BALASTNO NATOVAREN BROD SA 10% ZALIHA	Divisioni 3, 4 i 5 bez:	**Kriteriji stabiliteta u oštećenom stanju**			105664
	hold_2.c	(1) Kut ravnoteže	< 25°	1,54°	
	hold_1.c	(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	130,93°	
		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	4,837	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	6,3196	
STANJE OŠTEĆENJA 55, BALASTNO NATOVAREN BROD SA 10% ZALIHA	Divisioni 3, 4 i 5	**Kriteriji stabiliteta u oštećenom stanju**			-63675
		(1) Kut ravnoteže	< 25°	0,63°	
		(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	129,68°	
		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	7,982	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	8,0664	
STANJE OŠTEĆENJA 56, BALASTNO NATOVAREN BROD SA 10% ZALIHA	Divisioni 4, 5 i 6 bez:	**Kriteriji stabiliteta u oštećenom stanju**			105957
	hold_1.c	(1) Kut ravnoteže	< 25°	0,36°	
		(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	134,37°	
		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	5,043	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	6,5248	
STANJE OŠTEĆENJA 57, BALASTNO NATOVAREN BROD SA 10% ZALIHA	Divisioni 4, 5 i 6	**Kriteriji stabiliteta u oštećenom stanju**			118854
		(1) Kut ravnoteže	< 25°	0,41°	
		(2) Raspon kuteva od stanja ravnoteže do GZ = 0	> 20°	134,32°	
		(3) GZ u tom rasponu kuteva mora biti	> 0.1 m	5,043	
		(4) Površina ispod krivulje od kuta ravnoteže do GZ = 0	> 0.0175 m-rad	6,4510	



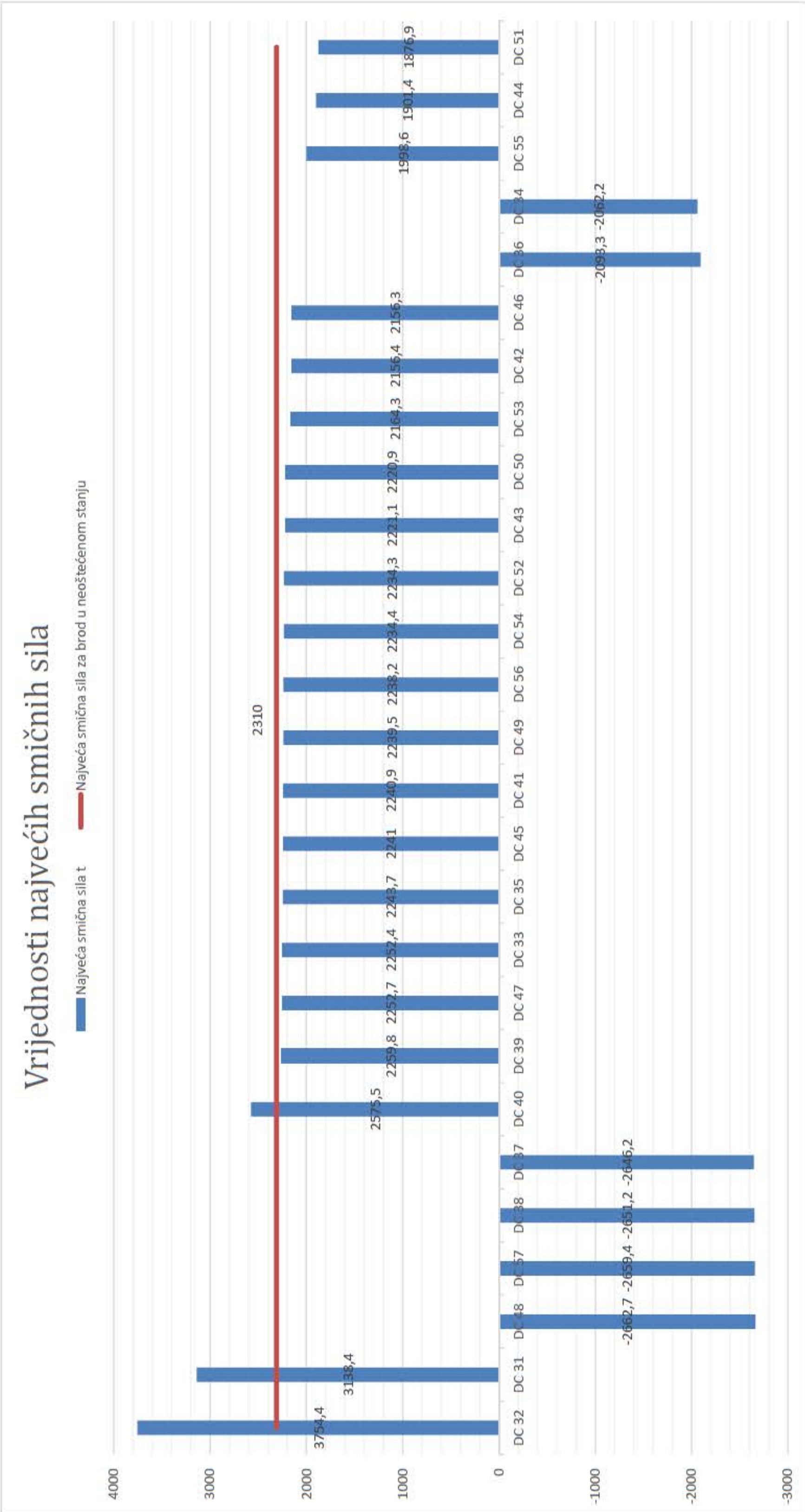
Slika 17. Vrijednosti najvećih momenata savijanja za LC 1



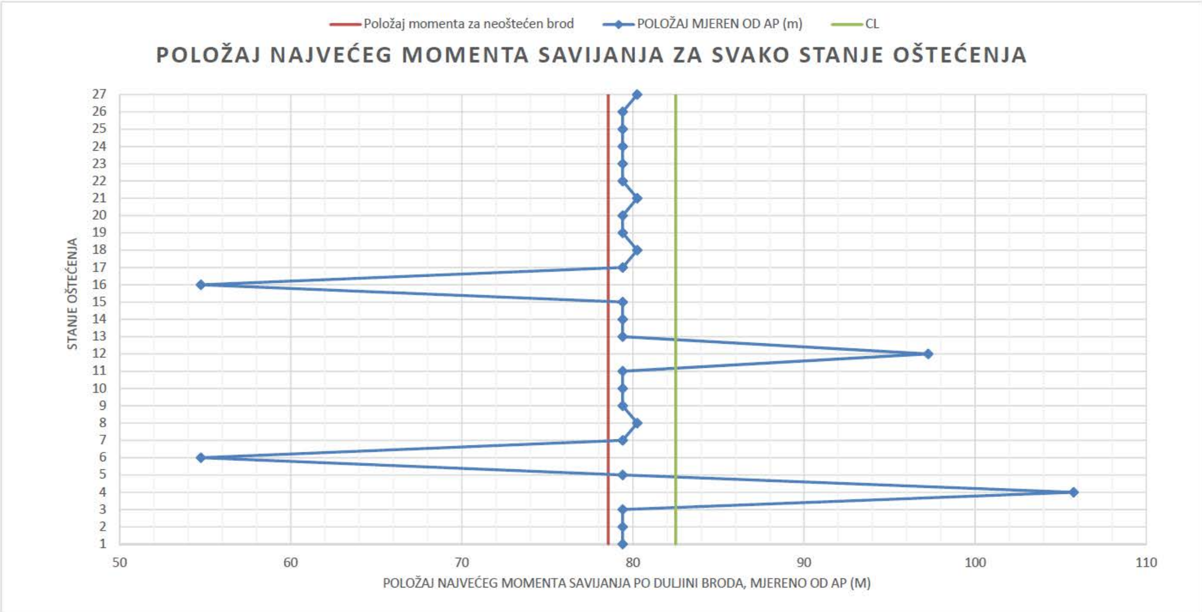
Slika 18. Vrijednosti najvećih momenata savijanja za LC 2



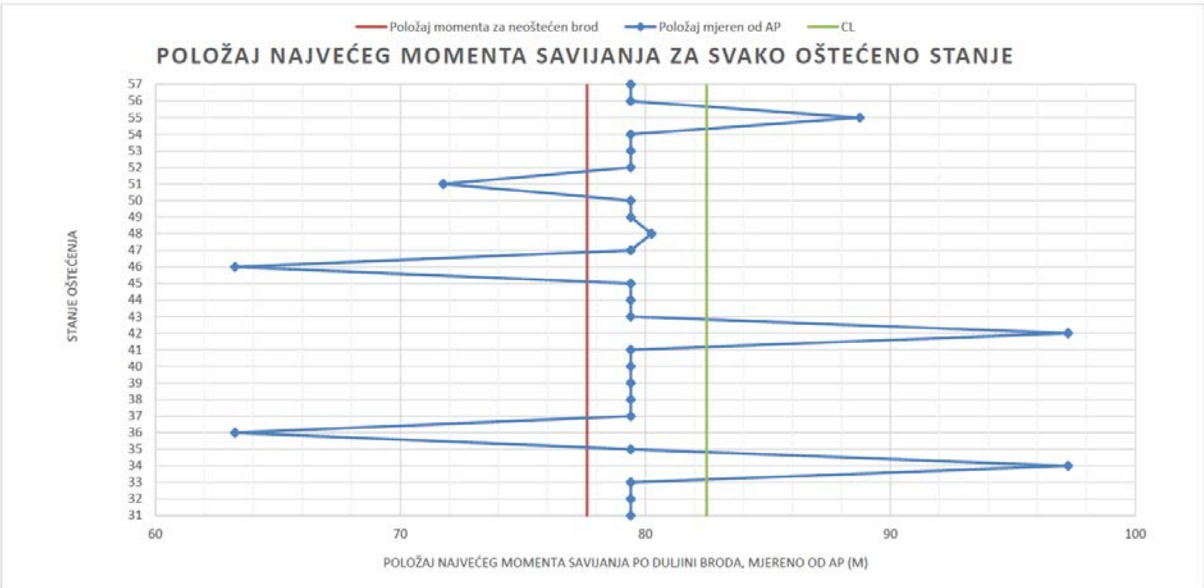
Slika 19. Vrijednosti najvećih smičnih sila za LC 1



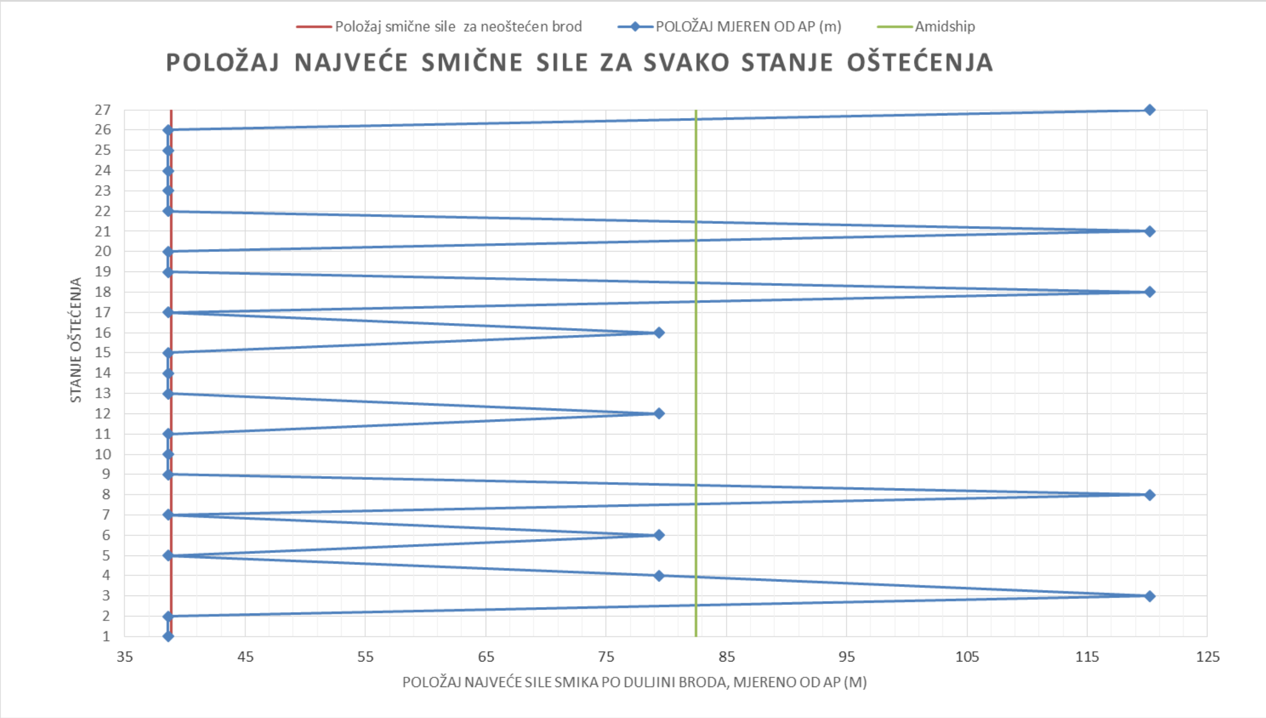
Slika 20. Vrijednosti najvećih smičnih sila za LC 2



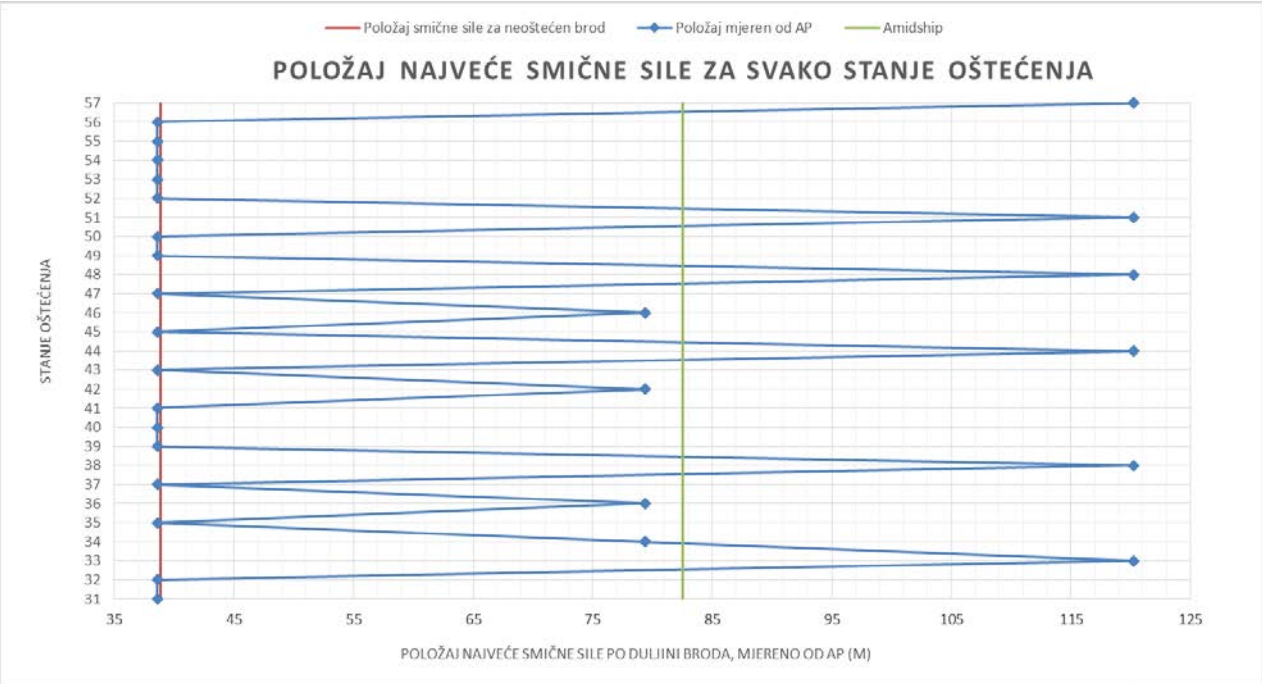
Slika 21. Položaj najvećeg momenta savijanja po duljini broda za LC 1



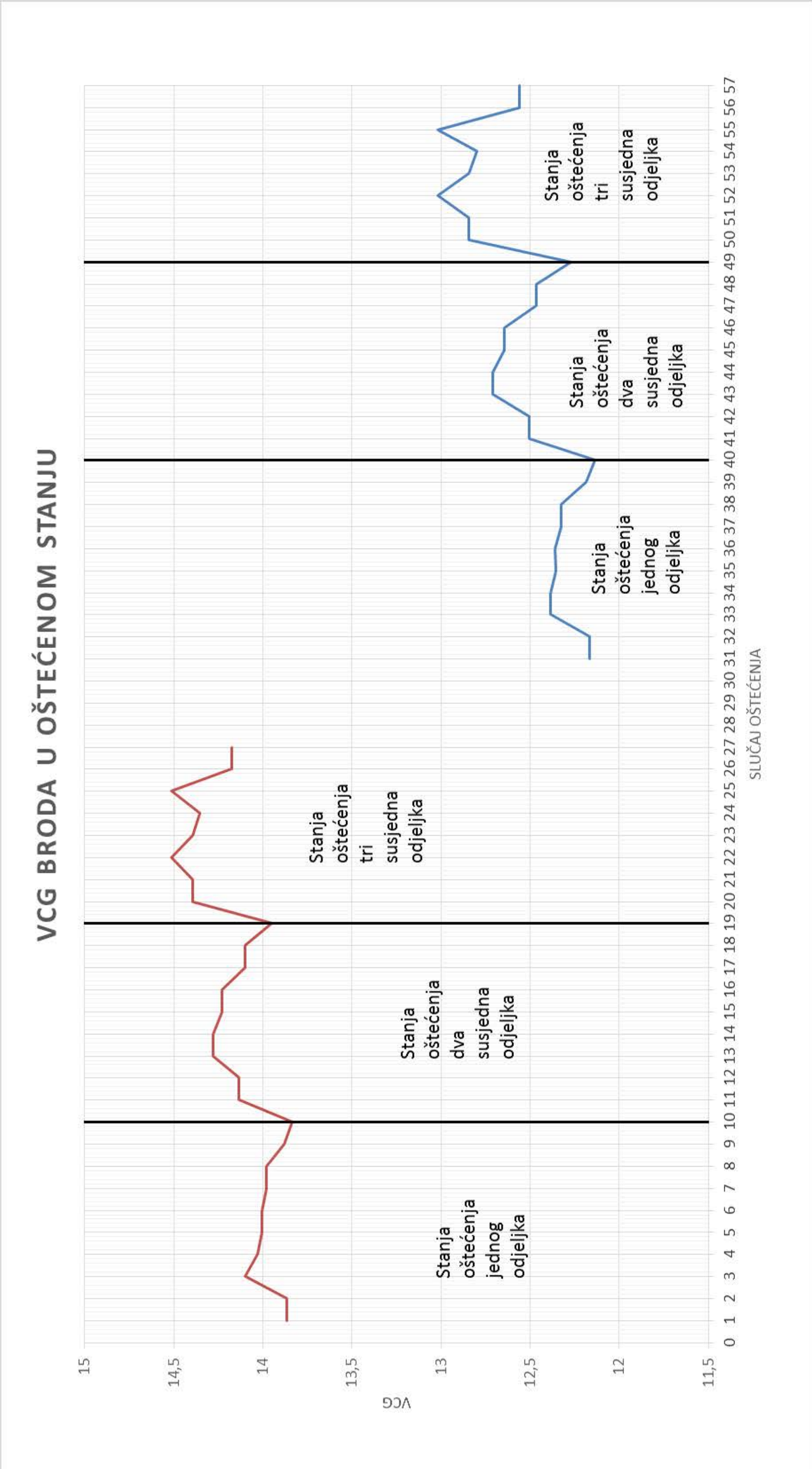
Slika 22. Položaj najvećeg momenta savijanja po duljini broda za LC 2



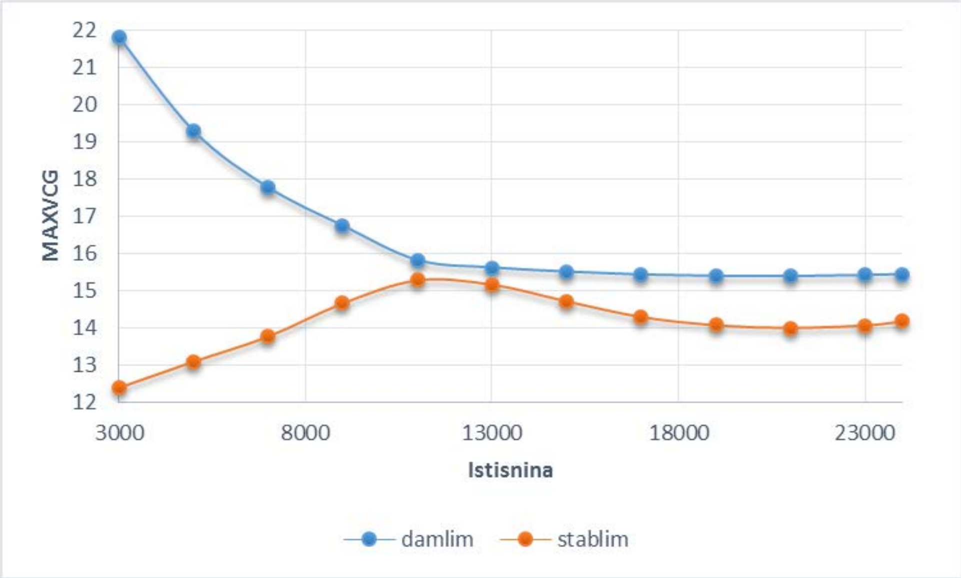
Slika 23. Položaj najveće smične sile po duljini broda za LC 1



Slika 24. Položaj najveće smične sile po duljini broda za LC 2



Slika 25. VCG broda u oštećenom stanju



Slika 26. Krivulja MAXVCG za LC 1 kriterijima za brod u oštećenom stanju i kriterijima za brod u neoštećenom stanju

7. PRORAČUN STABILITETA VJEROJATNOSNOM METODOM

7.1. Zahtijevani indeks pregrađivanja *R*

Zahtjevni indeks pregrađivanja *R* postavlja granicu sigurnosti stabiliteta u oštećenom stanju za brodove za prijevoz tereta, što znači da bi neki brod zadovoljio IMO standarde za sigurnost, njegov postignuti indeks pregrađivanja *A* mora biti veći od zahtjevnog *R*, odnosno *A* > *R*. Ovaj indeks ovisi isključivo o pregradnoj duljini broda, tako da je za veće brodove potreban veći indeks.

Na slijedećim stranicama je prikazana metodologija proračuna vrijednosti *A* i *R* za ro-ro teretne brodove, te je prikazana usporedba nekolicine značajnijih starih pravila s novim.

Po starim pravilima:

$$R = (0,002 + 0,0009 \cdot L_S)^{\frac{1}{3}}$$

Po novim pravilima IMO MSC.216(82):

$$R = 1 - \frac{128}{L_S + 152} \qquad \text{; za brodove dulje od 100 m}$$

Za usporedbu, kada zadamo proizvoljnu pregradnu duljinu 120 m, dobijemo ovakve rezultate:

$$R_1 = (0,002 + 0,0009 \cdot L_S)^{\frac{1}{3}} = (0,002 + 0,0009 \cdot 120)^{\frac{1}{3}} = (0,11)^{\frac{1}{3}} = 0,4791$$

$$R_2 = 1 - \frac{128}{L_S + 152} = 1 - \frac{128}{120 + 152} = 1 - \frac{128}{272} = 0,5294$$

Zaključno, nova pravila za brod iste pregradne duljine zahtijevaju minimalno 10.5% veći postignuti indeks pregrađivanja nego li je to prethodno bilo potrebno.

7.2. Postignuti indeks pregrađivanja *A*

Postignuti indeks pregrađivanja koji je u IMO propisima označen s *A* mora biti veći od zahtijevanog indeksa pregrađivanja *R*. Indeks pregrađivanja *A* određuje se prema literaturi [9] slijedećim izrazom:

$$A = \sum p_i s_i$$

gdje su:

i predstavlja svaki odjeljak ili skupinu odjeljaka koje se razmatraju

p_i parametar koji uzima u obzir vjerojatnost naplavljivanja jednog odjeljka, ili skupine susjednih odjeljaka, zanemarujući učinak bilo kojeg horizontalnog pregrađivanja

s_i parametar koji uzima u obzir vjerojatnost preživljavanja nakon naplavljivanja odjeljka ili skupine susjednih odjeljaka koji se razmatraju, uključujući učinak bilo kakvog horizontalnog pregrađivanja.

Parametar p_i za svaki odjeljak ili grupu odjeljaka se određuje na sljedeći način:

U slučaju oštećenja jedne zone:

$$p_i = p(x_{1(j)}, x_{2(j)}) \cdot \left[r\left(x_{1(j)}, x_{2(j)}, b_k\right) - r\left(x_{1(j)}, x_{2(j)}, b_{(k-1)}\right) \right]$$

U slučaju oštećenja dvije susjedne zone:

$$\begin{aligned} p_i = p(x_{1(j)}, x_{2(j+1)}) \cdot \left[r\left(x_{1(j)}, x_{2(j+1)}, b_k\right) - r\left(x_{1(j)}, x_{2(j+1)}, b_{(k-1)}\right) \right] - \\ p(x_{1(j)}, x_{2(j)}) \cdot \left[r\left(x_{1(j)}, x_{2(j)}, b_k\right) - r\left(x_{1(j)}, x_{2(j)}, b_{(k-1)}\right) \right] - \\ p(x_{1(j+1)}, x_{2(j+1)}) \cdot \left[r\left(x_{1(j+1)}, x_{2(j+1)}, b_k\right) - r\left(x_{1(j+1)}, x_{2(j+1)}, b_{(k-1)}\right) \right] \end{aligned}$$

U slučaju oštećenja tri ili više susjednih zona:

$$\begin{aligned} p_i = p(x_{1(j)}, x_{2(j+n-1)}) \cdot \left[r\left(x_{1(j)}, x_{2(j+n-1)}, b_k\right) - r\left(x_{1(j)}, x_{2(j+n-1)}, b_{(k-1)}\right) \right] - \\ p(x_{1(j)}, x_{2(j+n-2)}) \cdot \left[r\left(x_{1(j)}, x_{2(j+n-2)}, b_k\right) - r\left(x_{1(j)}, x_{2(j+n-2)}, b_{(k-1)}\right) \right] - \\ p(x_{1(j+1)}, x_{2(j+n-1)}) \cdot \left[r\left(x_{1(j+1)}, x_{2(j+n-1)}, b_k\right) - r\left(x_{1(j+1)}, x_{2(j+n-1)}, b_{(k-1)}\right) \right] - \\ p(x_{1(j+1)}, x_{2(j+n-2)}) \cdot \left[r\left(x_{1(j+1)}, x_{2(j+n-2)}, b_k\right) - r\left(x_{1(j+1)}, x_{2(j+n-2)}, b_{(k-1)}\right) \right] \end{aligned}$$

Pri čemu je:

$$r(x_1, x_2, b_0) = 0$$

j Broj zone oštećenja najbliže krmi, ukoliko je zona najbliža pramcu prva

n Broj susjednih oštećenih zona

k Faktor uzdužnog pregrađivanja koje sprječava prodor u poprečnom pogledu.

$k = 0$ na boku broda

x_1 Udaljenost od krmenog terminala pregradne duljine do točke zone oštećenja najbliže krmi.

x_2 Udaljenost od krmenog terminala pregradne duljine do točke zone oštećenja najbliže pramcu.

b Srednja poprečna udaljenost, u metrima, mjerena okomito na središnjicu, pri najdubljem pregradnom gazu između boka i pretpostavljene vertikalne ravnine.

Faktor s_i se određuje za svaki slučaj pretpostavljenog naplavljivanja koje uključuje odjeljak ili grupu odjeljaka.

$$s_i = K\left[\frac{GZ_{\max}}{0{,}12} \cdot \frac{Range}{16}\right]^{\frac{1}{4}}$$

Pri čemu su:

$GZ_{\max}$ Maksimalna pozitivna poluga stabiliteta, u metrima, do kuta $\theta\varpi$. Ne smije se uzimati veća od 0.12 *m*

Range Raspon pozitivnih poluga stabiliteta, u stupnjevima, mjerena od kuta θe. Pozitivan raspon se mjeri do $\theta\varpi$. Raspon se ne uzima veći od 16°.

$\theta\varpi$ Kut pri kojem vrijednost poluge stabiliteta postaje negativna, ili kut pri kojem otvor koji se ne može učiniti nepropusnim na vremenske uvijete postane potopljen.

θe Konačni kut nagiba broda u ravnotežnom stanju, u stupnjevima.

Ukoliko je:

- $\theta_e \leq \theta_{min} : K = 1$
- $\theta_e \geq \theta_{min} : K = 0$

U suprotnom slučaju:

$$K = \sqrt{\frac{\theta_{max} - \theta_e}{\theta_{max} - \theta_{\min}}}$$

Gdje su:

$$\theta_{\min} = 25° \alpha v \delta$$
$$\theta_{max} = 30°$$

U svim slučajevima s_i se treba uzeti kao nula gdje konačna vodna linija potapa:

- Donje rubove kritičnih točaka kroz koje je moguća progresivna naplava, a da nije prethodno uračunata u faktor s_i. Uglavnom uključuje sve otvore koji su nepropusni na vremenske uvijete, a ne uključuje otvore koji su vodonepropusni.
- Uron bilo kakvog okomitog evakuacijskog okna na glavnoj palubi.
- Uron strojeva i kontrola za upravljanje vodonepropusnim vratima, ventilima, cijevima ili ventilacijskim vodovima, a da ti strojevi i kontrole nisu dostupni iznad glavne palube.
- Uron bilo kojeg dijela ventilacijskih vodova ili cjevovoda koji prolaze kroz vodonepropusne pregrade a da je uključen u zone oštećenja. Ukoliko nisu opremljeni mehanizmom za zatvaranje na svakoj pregradi.

Faktor v_m se dobiva formulom:

$$v_m = v(H_{j,n,m}, d) - v(H_{j,n,m-1}, d)$$

Općenito svaki doprinos dobivenom indeksu pregrađivanja dA se dobija preko sljedeće formule:

$$dA = p_i \cdot \left[v_1 \cdot s_{\min 1} + (v_2 - v_1) \cdot s_{\min 2} + ... + (1 - v_{m-1}) \cdot s_{\min m} \right]$$

Konačni indeks pregrađivanja A dobije se kao suma djelomičnih indeksa A_S, A_P i A_L koji su izračunati na gazovima d_S, d_P i d_L. Dodatno, zahtjeva se da niti jedan od djelomičnih indeksa pregrađivanja ne bude manji od $0,5R$.

$$A = 0,4A_S + 0,4A_P + 0,2A_L$$

Kod određivanja vrijednosti A uzima se da brod plovi na ravnoj vodnoj liniji u slučajevima gazova d_S i d_P. U slučaju d_L gaza, uzima se trim u eksploataciji.

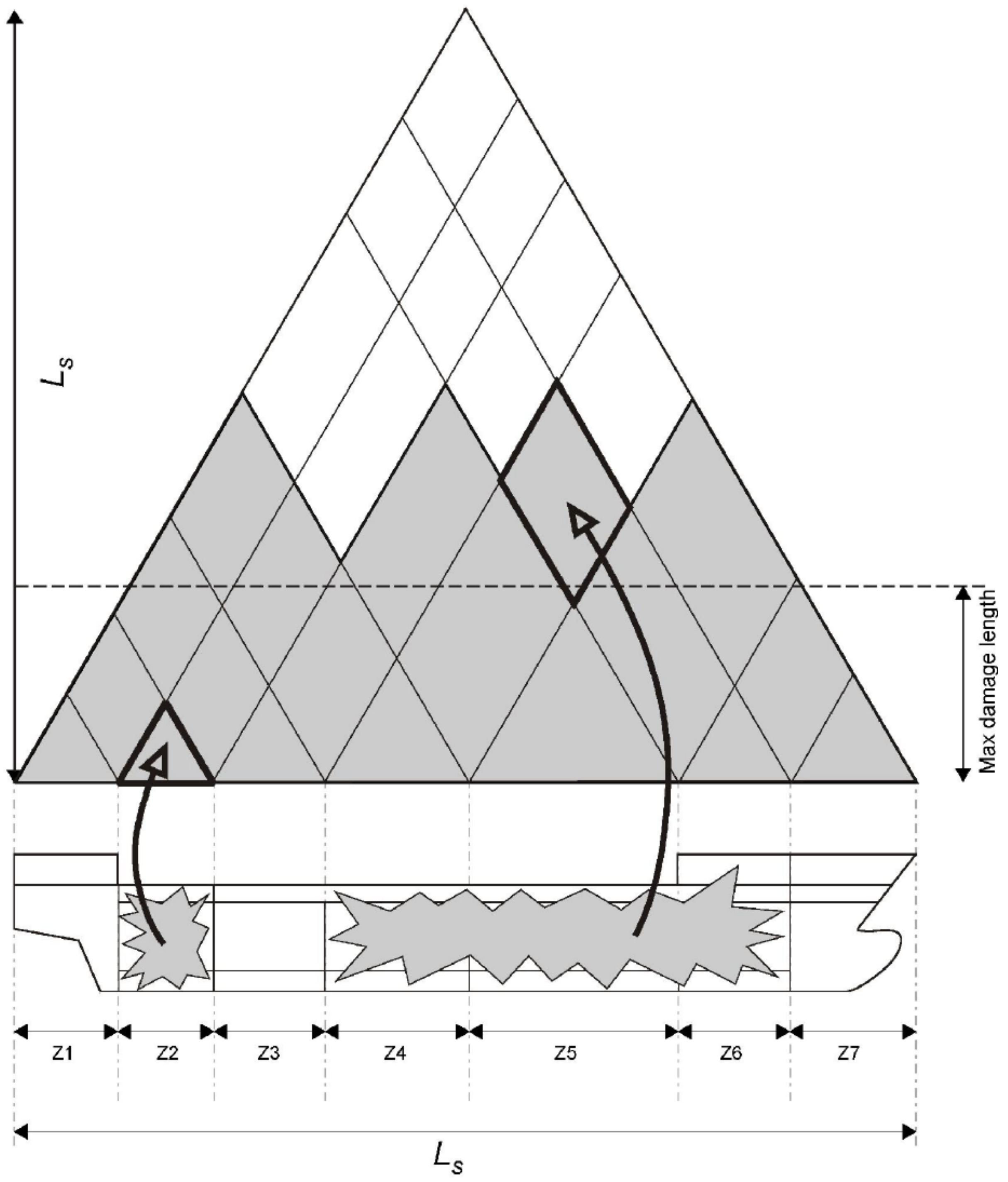
Vjerojatnost naplavljivanja odjeljka jednaka je vjerojatnosti svih oštećenja koja naplavljuju razmatrani odjeljak. Vjerojatnost da se brod neće prevrnuti ili potonuti kada se naplavi razmatani odjeljak ovisi o čitavom nizu slučajnih veličina, kao što su:

- osnovne karakteristike broda,
- početni gaz broda,
- metacentarska visina , *GM*
- koeficijent naplavljivosti prostora,
- vremenske prilike, itd.

Sve su to slučajne veličine u trenutku kada je brod oštećen. Vjerojatnost preživljavanja oštećenja određuje se formulom za ukupnu vjerojatnost kao zbroj umnožaka vjerojatnosti oštećenja za svaki odjeljak ili skupinu odjeljaka s vjerojatnosti preživljavanja oštećenja tog odjeljka ili skupine odjeljaka. Taj princip je prikazan tzv. trokutom vjerojatnosti. [Slika 27.]

Nedostaci ove metode na koje se nailazi tijekom njene primjene su:

- Nedovoljno točno određena funkcija razdiobe vjerojatnosti s obzirom na trenutno dostupnu statistiku o oštećenjima. Ova statistika uzima u obzir brodove koji su potonuli, a ne i ostale slučajeve kod kojih su brodovi bili lakše oštećeni,
- Stvarni kriterij za vjerojatnost preživljavanja oštećenja. Neka stanja oštećenja koja ispadaju kritična primjenom ove metode nisu kritična u stvarnosti za brod,
- Određivanje prikladnih stanja krcanja. Fiktivno stanje krcanja je i dalje prisutno u novim pravilima, d_P.
- Pravilan opis otvora i točki progresivnog naplavljivanja i cjevovoda za sprječavanje nesimetrične naplave. Indeks pregrađivanja treba biti jednak za dani brod bez obzira kojim ga programom proračunavamo i u kojem projektnom uredu.
- Određivanje stvarnih koeficijenata naplavljivosti pojedinih prostora.
- Opis procesa naplavljivanja



Slika 27. Grafički prikaz teoretskog trokuta vjerojatnosti

7.3. Rezultati dobiveni vjerojatnosnom metodom

U svrhu istraživanja i usporedbe između novih i starih pravila za vjerojatnosni pristup stabilitetu oštećenog broda izračunat je stabilitet i po staroj metodi, samo koristeći kvalitetniji model i bolje definirana stanja krcanja. Po starim pravilima, koristile su se samo dvije vodne linije za procjenu stabiliteta u oštećenom stanju. Tj. dva stanja krcanja broda. Jedno od ta dva stanja, najdublji pregradni gaz, je realno stanje, te se nalazi u knjizi trima i stabiliteta za svaki brod, na problem nailazimo kod drugog stanja, koje je fiktivno, parcijalni pregradni gaz, i veoma vjerojatno nije prikazano u knjizi trima i stabiliteta. Određeno je kao vodna linija koja odgovara gazu praznog opremljenog broda uvećanog za 60% razlike između gaza praznog opremljenog broda i gaza najviše pregradne linije. S time u skladu, po starim pravilima bile su određene dvije vodne linije:

$$d_F = 8.750 \text{ m}$$

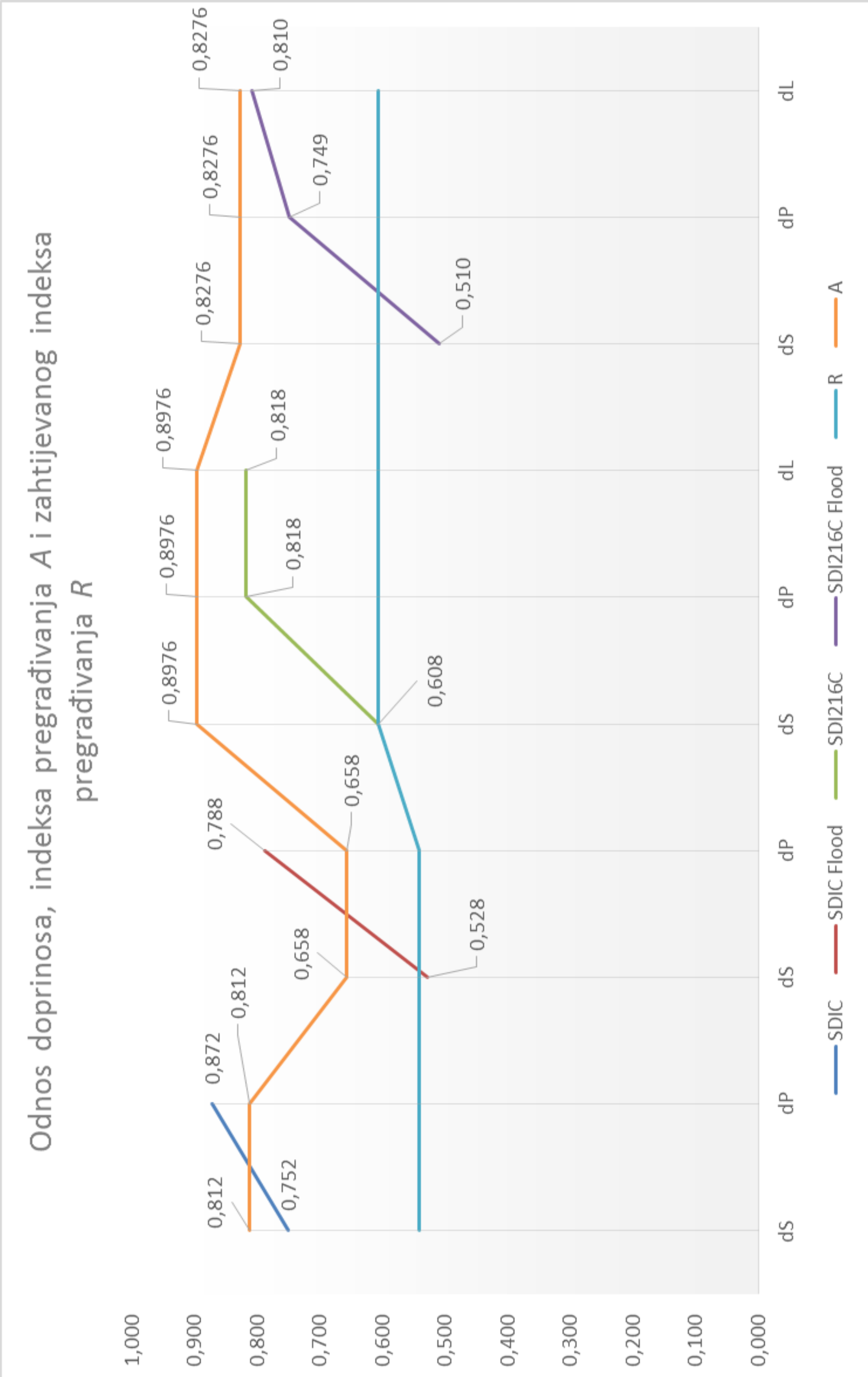
$$d_P = 7.269 \text{ m}$$

Za ta stanja, proračunat je stabilitet dva puta. Jednom gledajući sve kritične točke kao točke progresivne naplave, i jednom uzimajući u obzir nepropusnost na vremenske uvijete nekih od kritičnih točaka. Ovo je napravljeno kako bi se istražio utjecaj na postignuti indeks pregrađivanja pri oštećivanju odjeljaka, te se s te dvije promjene dobiju dva različita izlaza iz proračuna.

Po MSC.216(82) rezoluciji zahtjeva se proračun na tri vodne linije određene sljedećim gazovima:

d_S	Najdublji pregradni gaz, vodna linija koja odgovara ljetnoj vodnoj liniji broda.
d_L	Gaz pri lakoj eksploataciji, gaz u eksploataciji koji odgovara najmanjem predviđenom stanju krcanja sa uključenom dovoljnom količinom balasta za stabilitet i zagažaj.
d_P	Djelomični pregradni gaz, iznosi 60% razlike između gaza pri lakoj eksploataciji i najdubljeg pregradnog gaza.

Za karakteristični brod, d_S odgovara stanju broda nakrcanog sa 100% zaliha i homogeno nakrcanim teretom. d_L odgovara stanju broda sa 10% zaliha u balastnom stanju korigiranom za potrošene zalihe. d_P je fiktivna vodna linija i ne odgovara niti jednom stanju krcanja broda, te je stoga određena oduzimanjem mase brodu sa 100% zaliha i homogeno nakrcanim teretom, pri istom trimu, LCG i TCG vrijednostima.



Slika 28. Prikaz odnosa doprinosa, indeksa pregrađivanja *A* i zahtijevanog indeksa pregrađivanja *R*

Iz rezultata vjerojatnosne metode [Tablica 24. i Slika 28.] vidi se da je brod zadovoljio i proračun po prethodnim pravilima i proračun po aktualnim pravilima. Zadovoljen je i kriterij da svaki od doprinosa mora biti veći od 0,5*R*. Također, kriterij je zadovoljen uzevši u obzir redefiniciju kritičnih točaka, odnosno zanemarivanje nepropusnosti na vremenske uvijete nekih od kritičnih točaka (Sve kritične točke sa TIGHT oznakom postale su FLOOD).

Konačni indeks pregrađivanja *A* dobije se kao suma djelomičnih indeksa A_S, A_P i A_L koji su izračunati na gazovima d_S, d_P i d_L. Dodatno, zahtjeva se da niti jedan od djelomičnih indeksa pregrađivanja ne bude manji od $0,5R$ [9].

$$A = 0,4A_S + 0,4A_P + 0,2A_L$$

Za prethodna pravila [4] konačni indeks pregrađivanja *A* dobije se kao suma doprinosa indeksa pregrađivanja na gazovima.

$$A = \frac{A_S + A_P}{2}$$

Tablica 24. Rezultati vjerojatnosne metode

<table>
<tr><th>Metoda i vodna linija</th><th>Doprinos</th><th>R</th><th>$0.5R$</th><th>Kritične točke</th><th>A</th><th>Tablica sa rezultatima</th></tr>
<tr><td>SDIC d_S</td><td>0,752</td><td rowspan="4">0,542</td><td rowspan="4">**0,271**</td><td>TIGHT</td><td rowspan="2">**0,812**</td><td>Tablica 25.</td></tr>
<tr><td>SDIC d_P</td><td>0,872</td><td>TIGHT</td><td>Tablica 26.</td></tr>
<tr><td>SDIC flood d_S</td><td>0,528</td><td>FLOOD</td><td rowspan="2">**0,658**</td><td>Tablica 27.</td></tr>
<tr><td>SDIC flood d_P</td><td>0,788</td><td>FLOOD</td><td>Tablica 28.</td></tr>
<tr><td>SDI216C d_S</td><td>0,608</td><td rowspan="6">0,608</td><td rowspan="6">**0,304**</td><td>TIGHT</td><td rowspan="3">**0,8976**</td><td>Tablica 29.</td></tr>
<tr><td>SDI216C d_P</td><td>0,818</td><td>TIGHT</td><td>Tablica 30.</td></tr>
<tr><td>SDI216C d_L</td><td>0,818</td><td>TIGHT</td><td>Tablica 31.</td></tr>
<tr><td>SDI216C flood d_S</td><td>0,510</td><td>FLOOD</td><td rowspan="3">**0,8276**</td><td>Tablica 32.</td></tr>
<tr><td>SDI216C flood d_P</td><td>0,749</td><td>FLOOD</td><td>Tablica 33.</td></tr>
<tr><td>SDI216C flood d_L</td><td>0,810</td><td>FLOOD</td><td>Tablica 34.</td></tr>
</table>

Tablica 25. Rezultati prethodnih proračuna vjerojatnosnom metodom, d_S vodna linija, TIGHT kritične točke

```
DEEPEST SUBDIVISION DRAUGHT: HOMOGENOUS LOADED, 100% STORES
                            T=8.750 m


                         PERMEABILITY SETTINGS
        Name          Description            Perm.     Cubic METERS
        ------------------------------------------------------------
        HOLD_4.C                            0.7000*       2,821.814
        HOLD_3.C                            0.7000*      10,048.353
        HOLD_2.C                            0.7000*       9,761.961
        HOLD_1.C                            0.7000*       3,767.363
        ------------------* Permeability override-------------------


                    PROBABILISTIC DAMAGE STABILITY
                         Cargo Vessel Version
         Subdivision length: 174.350   Terminals: 170.450f, 3.900a
               Breadth: 31.132   Draft: 8.736   Hmax: 15.095

Divisions-------P------Smin--P*S*V----A-----Depth--Trim----Heel---Range--MaxRA
None         0.00000  1.000  0.000  0.000  10.187  1.00a   1.96s  44.21  0.740
6            0.01400  1.000  0.014  0.014  10.200  1.02a   1.95s  44.12  0.745
5            0.02108  1.000  0.021  0.035  10.155  0.97a   1.98s  44.16  0.752
4            0.09023  1.000  0.090  0.125   9.664  0.31a   2.59s  43.92  0.673
3            0.18477  1.000  0.185  0.310   9.957  0.41f   2.59s  41.37  0.647
2            0.15051  1.000  0.151  0.461  12.376  1.46a   6.48s  31.41  0.930
1            0.11536  0.000  0.000  0.461  13.307  2.80a   7.59s   0.00  0.000
-------------- 1-division damage:   0.461  Probability of damage: 0.576  -----

6+5          0.02793  1.000  0.028  0.489  10.169  0.98a   1.97s  44.06  0.756
5+4          0.05601  1.000  0.056  0.545   9.536  0.16a   2.74s  43.83  0.691
4+3          0.09112  1.000  0.091  0.636   9.084  1.80f   3.49s  40.66  0.936
3+2          0.09231  1.000  0.092  0.728  12.808  0.05a   6.46s  28.69  1.388
2+1          0.06320  0.000  0.000  0.728  17.202  3.92a   6.06s   0.00  0.000
-------------- 2-division damage:   0.267  Probability of damage: 0.331  -----

6+5+4        0.02409  1.000  0.024  0.752   9.531  0.16a   2.75s  43.79  0.697
5+4+3        0.00481  0.000  0.000  0.752   8.759  2.26f   3.01s   0.00  0.000
4+3+2        0.00000  0.000  0.000  0.752  12.355  1.23f   2.80s   0.00  0.001
3+2+1        0.00000  0.000  0.000  0.752  17.404  2.16a   3.59s   0.00  0.001
-------------- 3-division damage:   0.024  Probability of damage: 0.029  -----

6+5+4+3      0.00006  0.000  0.000  0.752   8.562  2.51f   2.51s   0.00  0.000
-------------- 4-division damage:   0.000  Probability of damage: 0.000  -----

Attained index in this condition:   0.752  Total probability of damage: 0.935
Required index:                     0.542
Distances in METERS.------------------------------------------Angles in deg.
```

Tablica 26. Rezultati prethodnih proračuna vjerojatnosnom metodom, d_P vodna linija, TIGHT kritične točke

PARTIAL SUBDIVISION DRAUGHT: REDUCED HOMOGENOUS LOADED, 100% STORES
T=7.269 m

PERMEABILITY SETTINGS

Name	Description	Perm.	Cubic METERS
HOLD_4.C		0.7000*	2,821.814
HOLD_3.C		0.7000*	10,048.353
HOLD_2.C		0.7000*	9,761.961
HOLD_1.C		0.7000*	3,767.363

-------------------* Permeability override-------------------

PROBABILISTIC DAMAGE STABILITY
Cargo Vessel Version
Subdivision length: 174.350 Terminals: 170.450f, 3.900a
Breadth: 31.132 Draft: 7.257 Hmax: 13.616

Divisions	P	Smin	P*S*V	A	Depth	Trim	Heel	Range	MaxRA
None	0.00000	1.000	0.000	0.000	8.709	1.00a	1.96s	51.11	1.269
6	0.01400	1.000	0.014	0.014	8.755	1.05a	1.95s	50.97	1.280
5	0.02108	1.000	0.021	0.035	8.748	1.05a	1.94s	50.98	1.289
4	0.09023	1.000	0.090	0.125	8.288	0.52a	2.31s	50.96	1.203
3	0.18477	1.000	0.185	0.310	8.372	0.24f	4.17s	46.75	1.045
2	0.15051	1.000	0.151	0.461	10.745	1.48a	4.48s	41.73	1.163
1	0.11536	1.000	0.115	0.576	10.818	2.17a	1.66s	44.97	1.273
------------- 1-division damage:				0.576	Probability of damage:			0.576	-----
6+5	0.02793	1.000	0.028	0.604	8.800	1.10a	1.92s	50.84	1.299
5+4	0.05601	1.000	0.056	0.660	8.277	0.51a	2.31s	50.86	1.221
4+3	0.09112	1.000	0.091	0.751	7.283	1.61f	5.37s	45.65	1.224
3+2	0.09231	1.000	0.092	0.843	10.937	0.11a	5.30s	38.25	1.229
2+1	0.06320	0.000	0.000	0.843	15.139	3.77a	7.53s	0.00	0.000
------------- 2-division damage:				0.267	Probability of damage:			0.331	-----
6+5+4	0.02409	1.000	0.024	0.867	8.319	0.55a	2.29s	50.74	1.233
5+4+3	0.00481	1.000	0.005	0.872	6.828	2.10f	5.26s	45.84	1.318
4+3+2	0.00000	1.000	0.000	0.872	10.357	1.24f	5.06s	38.50	1.604
3+2+1	0.00000	0.000	0.000	0.872	15.694	2.35a	6.24s	0.00	0.000
------------- 3-division damage:				0.029	Probability of damage:			0.029	-----
6+5+4+3	0.00006	1.000	0.000	0.872	6.539	2.40f	5.19s	45.90	1.358
------------- 4-division damage:				0.000	Probability of damage:			0.000	-----

Attained index in this condition: 0.872 Total probability of damage: 0.935
Required index: 0.542
Distances in METERS.---Angles in deg.

Tablica 27. Rezultati prethodnih proračuna vjerojatnosnom metodom, d_S vodna linija, FLOOD kritične točke

```
DEEPEST SUBDIVISION DRAUGHT: HOMOGENOUS LOADED, 100% STORES
                         T=8.750 m


                         PERMEABILITY SETTINGS
        Name           Description             Perm.     Cubic METERS
        ------------------------------------------------------------
        HOLD_4.C                              0.7000*       2,821.814
        HOLD_3.C                              0.7000*      10,048.353
        HOLD_2.C                              0.7000*       9,761.961
        HOLD_1.C                              0.7000*       3,767.363
        ------------------* Permeability override-------------------


                    PROBABILISTIC DAMAGE STABILITY
                         Cargo Vessel Version
         Subdivision length: 174.350   Terminals: 170.450f, 3.900a
               Breadth: 31.132   Draft: 8.736   Hmax: 15.095

Divisions-------P------Smin--P*S*V----A-----Depth--Trim----Heel---Range--MaxRA
None         0.00000  1.000  0.000  0.000  10.187  1.00a   1.96s  20.12  0.740
6            0.01400  1.000  0.014  0.014  10.200  1.02a   1.95s  20.06  0.745
5            0.02108  1.000  0.021  0.035  10.155  0.97a   1.98s  20.35  0.752
4            0.09023  1.000  0.090  0.125   9.664  0.31a   2.59s  20.47  0.673
3            0.18477  0.870  0.161  0.286   9.957  0.41f   2.59s  15.14  0.436
2            0.15051  0.397  0.060  0.346  12.376  1.46a   6.48s   3.15  0.140
1            0.11536  0.000  0.000  0.346  13.306  2.80a   7.59s   0.00  0.000
-------------- 1-division damage:   0.346  Probability of damage: 0.576  -----

6+5          0.02793  1.000  0.028  0.374  10.169  0.98a   1.97s  20.28  0.756
5+4          0.05601  0.991  0.055  0.429   9.536  0.16a   2.74s  19.64  0.675
4+3          0.09112  0.466  0.043  0.472   9.084  1.80f   3.49s   4.35  0.151
3+2          0.09231  0.351  0.032  0.504  12.808  0.05a   6.46s   2.46  0.179
2+1          0.06320  0.000  0.000  0.504  17.202  3.92a   6.06s   0.00  0.000
-------------- 2-division damage:   0.158  Probability of damage: 0.331  -----

6+5+4        0.02409  0.989  0.024  0.528   9.531  0.16a   2.75s  19.56  0.677
5+4+3        0.00481  0.000  0.000  0.528   8.759  2.26f   3.01s   0.00  0.000
4+3+2        0.00000  0.000  0.000  0.528  12.355  1.23f   2.80s   0.00  0.001
3+2+1        0.00000  0.000  0.000  0.528  17.404  2.16a   3.59s   0.00  0.001
-------------- 3-division damage:   0.024  Probability of damage: 0.029  -----

6+5+4+3      0.00006  0.000  0.000  0.528   8.562  2.51f   2.51s   0.00  0.000
-------------- 4-division damage:   0.000  Probability of damage: 0.000  -----

Attained index in this condition:   0.528  Total probability of damage: 0.935
Required index:                     0.542
Distances in METERS.-------------------------------------------Angles in deg.
```

Tablica 28. Rezultati prethodnih proračuna vjerojatnosnom metodom, d_P vodna linija, FLOOD kritične točke

PARTIAL SUBDIVISION DRAUGHT: REDUCED HOMOGENOUS LOADED, 100% STORES
T=7.269 m

PERMEABILITY SETTINGS

Name	Description	Perm.	Cubic METERS
HOLD_4.C		0.7000*	2,821.814
HOLD_3.C		0.7000*	10,048.353
HOLD_2.C		0.7000*	9,761.961
HOLD_1.C		0.7000*	3,767.363

------------------* Permeability override-------------------

PROBABILISTIC DAMAGE STABILITY
Cargo Vessel Version
Subdivision length: 174.350   Terminals: 170.450f, 3.900a
Breadth: 31.132   Draft: 7.257   Hmax: 13.616

Divisions	P	Smin	P*S*V	A	Depth	Trim	Heel	Range	MaxRA
None	0.00000	1.000	0.000	0.000	8.709	1.00a	1.96s	29.47	1.269
6	0.01400	1.000	0.014	0.014	8.755	1.05a	1.95s	29.25	1.280
5	0.02108	1.000	0.021	0.035	8.748	1.05a	1.94s	29.32	1.289
4	0.09023	1.000	0.090	0.125	8.288	0.52a	2.31s	26.96	1.203
3	0.18477	1.000	0.185	0.310	8.372	0.24f	4.17s	20.38	1.045
2	0.15051	0.839	0.126	0.436	10.745	1.48a	4.48s	14.08	0.763
1	0.11536	0.817	0.094	0.531	10.816	2.17a	1.66s	13.36	0.818
-------------- 1-division damage:				0.531	Probability of damage: 0.576				-----
6+5	0.02793	1.000	0.028	0.559	8.800	1.10a	1.92s	29.08	1.299
5+4	0.05601	1.000	0.056	0.615	8.277	0.51a	2.31s	26.78	1.221
4+3	0.09112	0.809	0.074	0.688	7.283	1.61f	5.37s	13.09	0.605
3+2	0.09231	0.787	0.073	0.761	10.937	0.11a	5.30s	12.38	0.631
2+1	0.06320	0.000	0.000	0.761	15.139	3.77a	7.53s	0.00	0.000
-------------- 2-division damage:				0.230	Probability of damage: 0.331				-----
6+5+4	0.02409	1.000	0.024	0.785	8.319	0.55a	2.29s	26.88	1.233
5+4+3	0.00481	0.698	0.003	0.788	6.828	2.10f	5.26s	9.75	0.408
4+3+2	0.00000	0.427	0.000	0.788	10.357	1.24f	5.06s	3.64	0.262
3+2+1	0.00000	0.000	0.000	0.788	15.694	2.35a	6.24s	0.00	0.000
-------------- 3-division damage:				0.027	Probability of damage: 0.029				-----
6+5+4+3	0.00006	0.627	0.000	0.788	6.539	2.40f	5.19s	7.87	0.304
-------------- 4-division damage:				0.000	Probability of damage: 0.000				-----

Attained index in this condition: 0.788   Total probability of damage: 0.935
Required index: 0.542
Distances in METERS.--Angles in deg.

Tablica 29. Rezultati MSC.216(82) vjerojatnosne metode, d_S vodna linija, TIGHT kritične točke

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 DEEPEST SUBDIVISION DRAUGHT: HOMOGENOUS LOADED, 100% STORES
                        T=8.750 m


                         PERMEABILITY SETTINGS
          Name          Description            Perm.     Cubic METERS
          ------------------------------------------------------------
          HOLD_4.C                            0.9000*       3,628.047
          HOLD_3.C                            0.9000*      12,919.311
          HOLD_2.C                            0.9000*      12,551.093
          HOLD_1.C                            0.9000*       4,843.752
          ------------------* Permeability override-------------------


                 PROBABILISTIC DAMAGE STABILITY MSC.216(82)
                            Cargo Vessel Version
           Subdivision length: 174.350   Terminals: 170.450f, 3.900a
                        Breadth: 31.132   Draft: 8.736

Divisions-------P------Smin--P*S*V----A-----Depth--Trim----Heel---Range--MaxRA
None         0.00000  1.000  0.000  0.000  10.187  1.00a   1.96s  44.21  0.587
6            0.01486  1.000  0.015  0.015  10.200  1.02a   1.95s  44.12  0.591
5            0.02216  1.000  0.022  0.037  10.155  0.97a   1.98s  44.16  0.596
4            0.08803  1.000  0.088  0.125   9.431  0.01a   2.97s  43.61  0.505
3            0.16707  1.000  0.167  0.292   9.966  0.89f   2.24s  41.13  0.572
2            0.16707  1.000  0.167  0.459  13.475  1.66a   2.28s  32.17  0.890
1            0.21022  0.000  0.000  0.459  14.719  3.57a   3.07s   0.00  0.000
-------------- 1-division damage:   0.459  Probability of damage: 0.669  -----

6+5          0.02620  1.000  0.026  0.485  10.169  0.98a   1.97s  44.06  0.600
5+4          0.04256  1.000  0.043  0.528   9.254  0.19f   3.23s  43.43  0.516
4+3          0.06270  0.000  0.000  0.528   9.001  2.71f   1.18s   0.00  0.000
3+2          0.06654  1.000  0.067  0.594  14.558  0.11f   0.53s  29.18  1.901
2+1          0.06682  0.000  0.000  0.594  19.326  4.62a   0.65s   0.00  0.000
-------------- 2-division damage:   0.135  Probability of damage: 0.265  -----

6+5+4        0.01333  1.000  0.013  0.608   9.230  0.21f   3.27s  43.38  0.520
5+4+3        0.00353  0.000  0.000  0.608   8.784  2.99f   1.05s   0.00  0.000
4+3+2        0.00040  0.000  0.000  0.608  13.759  1.38f   0.44s   0.00  0.000
3+2+1        0.00040  0.000  0.000  0.608  19.302  2.28a   0.32s   0.00  0.000
-------------- 3-division damage:   0.013  Probability of damage: 0.018  -----

6+5+4+3      0.00068  0.000  0.000  0.608   8.552  3.24f   0.97s   0.00  0.000
5+4+3+2      0.00000  0.000  0.000  0.608  13.570  1.61f   0.43s   0.00  0.000
4+3+2+1      0.00000  0.000  0.000  0.608  18.404  0.88a   0.27s   0.00  0.000
-------------- 4-division damage:   0.000  Probability of damage: 0.001  -----

Attained index in this condition:   0.608  Total probability of damage: 0.953
Required index:                     0.608
Distances in METERS.--------------------------------------------Angles in deg.
```

Tablica 30. Rezultati MSC.216(82) vjerojatnosne metode, d_P vodna linija, TIGHT kritične točke

PARTIAL SUBDIVISION DRAUGHT: REDUCED HOMOGENOUS LOADED, 100% STORES
T=7.7884 m

PERMEABILITY SETTINGS

Name	Description	Perm.	Cubic METERS
HOLD_4.C		0.9000*	3,628.047
HOLD_3.C		0.9000*	12,919.311
HOLD_2.C		0.9000*	12,551.093
HOLD_1.C		0.9000*	4,843.752

------------------* Permeability override-------------------

PROBABILISTIC DAMAGE STABILITY MSC.216(82)
Cargo Vessel Version
Subdivision length: 174.350 Terminals: 170.450f, 3.900a
Breadth: 31.132 Draft: 7.776

Divisions	P	Smin	P*S*V	A	Depth	Trim	Heel	Range	MaxRA
None	0.00000	1.000	0.000	0.000	9.227	1.00a	1.96s	48.80	0.917
6	0.01486	1.000	0.015	0.015	9.254	1.03a	1.94s	48.71	0.925
5	0.02216	1.000	0.022	0.037	9.236	1.02a	1.95s	48.72	0.931
4	0.08803	1.000	0.088	0.125	8.550	0.19a	2.70s	48.29	0.854
3	0.16707	1.000	0.167	0.292	8.893	0.80f	3.06s	45.12	0.721
2	0.16707	1.000	0.167	0.459	12.229	1.61a	1.34s	39.35	1.055
1	0.21022	1.000	0.210	0.669	12.175	2.66a	1.54s	42.20	0.713
--------------	1-division damage:			0.669	Probability of damage:			0.669	-----
6+5	0.02620	1.000	0.026	0.696	9.267	1.05a	1.93s	48.62	0.938
5+4	0.04256	1.000	0.043	0.738	8.432	0.07a	2.78s	48.17	0.862
4+3	0.06270	0.000	0.000	0.738	7.535	2.94f	2.11s	0.00	0.000
3+2	0.06654	1.000	0.067	0.805	13.154	0.25f	1.23s	34.95	1.965
2+1	0.06682	0.000	0.000	0.805	18.318	4.66a	0.49s	0.00	0.000
--------------	2-division damage:			0.135	Probability of damage:			0.265	-----
6+5+4	0.01333	1.000	0.013	0.818	8.445	0.08a	2.77s	48.09	0.869
5+4+3	0.00353	0.000	0.000	0.818	7.204	3.34f	1.37s	0.00	0.000
4+3+2	0.00040	0.000	0.000	0.818	12.644	1.61f	0.41s	0.00	0.000
3+2+1	0.00040	0.000	0.000	0.818	18.374	2.21a	0.26s	0.00	0.000
--------------	3-division damage:			0.013	Probability of damage:			0.018	-----
6+5+4+3	0.00068	0.000	0.000	0.818	6.902	3.64f	1.15s	0.00	0.000
5+4+3+2	0.00000	0.000	0.000	0.818	12.454	1.84f	0.39s	0.00	0.000
4+3+2+1	0.00000	0.000	0.000	0.818	17.413	0.71a	0.20s	0.00	0.000
--------------	4-division damage:			0.000	Probability of damage:			0.001	-----

Attained index in this condition: 0.818 Total probability of damage: 0.953
Required index: 0.608
Distances in METERS.--Angles in deg.

Tablica 31. Rezultati MSC.216(82) vjerojatnosne metode, d_L vodna linija, TIGHT kritične točke

LOWEST SUBDIVISION DRAUGHT: BALLAST LOADED, 10% STORES
T=6.346 m

PERMEABILITY SETTINGS

Name	Description	Perm.	Cubic METERS
HOLD_4.C		0.9500	3,829.605
HOLD_3.C		0.9500	13,637.051
HOLD_2.C		0.9500	13,248.375
HOLD_1.C		0.9500	5,112.850

PROBABILISTIC DAMAGE STABILITY MSC.216(82)
Cargo Vessel Version
Subdivision length: 174.350 Terminals: 170.450f, 3.900a
Breadth: 31.132 Draft: 6.332

Divisions	P	Smin	P*S*V	A	Depth	Trim	Heel	Range	MaxRA
None	0.00000	1.000	0.000	0.000	7.785	1.00a	1.96s	55.01	1.004
6	0.01486	1.000	0.015	0.015	7.889	1.10a	1.96s	54.77	1.020
5	0.02216	1.000	0.022	0.037	7.918	1.13a	1.95s	54.72	1.032
4	0.08803	1.000	0.088	0.125	7.292	0.50a	2.25s	54.83	0.928
3	0.16707	1.000	0.167	0.292	7.256	0.89f	6.13s	47.86	0.776
2	0.16707	1.000	0.167	0.459	10.934	1.86a	1.03s	47.65	0.933
1	0.21022	1.000	0.210	0.669	10.326	2.41a	1.19s	49.68	0.924
1-division damage:				0.669	Probability of damage:			0.669	
6+5	0.02620	1.000	0.026	0.696	8.041	1.25a	1.94s	54.48	1.050
5+4	0.04256	1.000	0.043	0.738	7.419	0.62a	2.24s	54.51	0.956
4+3	0.06270	0.000	0.000	0.738	5.335	3.44f	4.66s	0.00	0.000
3+2	0.06654	1.000	0.067	0.805	11.697	0.30f	1.08s	42.54	1.559
2+1	0.06682	0.000	0.000	0.805	17.739	5.21a	0.28s	0.00	0.000
2-division damage:				0.135	Probability of damage:			0.265	
6+5+4	0.01333	1.000	0.013	0.818	7.551	0.74a	2.23s	54.24	0.974
5+4+3	0.00353	0.000	0.000	0.818	4.825	4.06f	1.87s	0.00	0.000
4+3+2	0.00040	0.000	0.000	0.818	11.331	1.98f	0.38s	0.00	0.000
3+2+1	0.00040	0.000	0.000	0.818	18.002	2.43a	0.14s	0.00	0.000
3-division damage:				0.013	Probability of damage:			0.018	
6+5+4+3	0.00068	0.000	0.000	0.818	4.447	4.44f	1.24s	0.00	0.000
5+4+3+2	0.00000	0.000	0.000	0.818	11.168	2.20f	0.35s	0.00	0.000
4+3+2+1	0.00000	0.000	0.000	0.818	16.912	0.66a	0.08s	0.00	0.000
4-division damage:				0.000	Probability of damage:			0.001	

Attained index in this condition: 0.818 Total probability of damage: 0.953
Required index: 0.608
Distances in METERS.--Angles in deg.

Tablica 32. Rezultati MSC.216(82) vjerojatnosne metode, d_S vodna linija, FLOOD kritične točke

DEEPEST SUBDIVISION DRAUGHT: HOMOGENOUS LOADED, 100% STORES
T=8.750 m

PERMEABILITY SETTINGS

Name	Description	Perm.	Cubic METERS
HOLD_4.C		0.9000*	3,628.047
HOLD_3.C		0.9000*	12,919.311
HOLD_2.C		0.9000*	12,551.093
HOLD_1.C		0.9000*	4,843.752

------------------* Permeability override-------------------

PROBABILISTIC DAMAGE STABILITY MSC.216(82)
Cargo Vessel Version
Subdivision length: 174.350 Terminals: 170.450f, 3.900a
Breadth: 31.132 Draft: 8.736

Divisions	P	Smin	P*S*V	A	Depth	Trim	Heel	Range	MaxRA
None	0.00000	1.000	0.000	0.000	10.187	1.00a	1.96s	20.12	0.587
6	0.01486	1.000	0.015	0.015	10.200	1.02a	1.95s	20.06	0.591
5	0.02216	1.000	0.022	0.037	10.155	0.97a	1.98s	20.35	0.596
4	0.08803	1.000	0.088	0.125	9.431	0.01a	2.97s	18.63	0.505
3	0.16707	0.927	0.155	0.280	9.966	0.89f	2.24s	11.83	0.391
2	0.16707	0.673	0.113	0.392	13.478	1.66a	2.28s	3.29	0.153
1	0.21022	0.000	0.000	0.392	14.719	3.57a	3.07s	0.00	0.000
-------------- 1-division damage:				0.392	Probability of damage: 0.669				-----
6+5	0.02620	1.000	0.026	0.419	10.169	0.98a	1.97s	20.28	0.600
5+4	0.04256	1.000	0.043	0.461	9.254	0.19f	3.23s	17.44	0.516
4+3	0.06270	0.000	0.000	0.461	9.001	2.71f	1.18s	0.00	0.000
3+2	0.06654	0.539	0.036	0.497	14.558	0.11f	0.53s	1.35	0.232
2+1	0.06682	0.000	0.000	0.497	19.326	4.62a	0.65s	0.00	0.000
-------------- 2-division damage:				0.105	Probability of damage: 0.265				-----
6+5+4	0.01333	1.000	0.013	0.510	9.230	0.21f	3.27s	17.22	0.520
5+4+3	0.00353	0.000	0.000	0.510	8.784	2.99f	1.05s	0.00	0.000
4+3+2	0.00040	0.000	0.000	0.510	13.759	1.38f	0.44s	0.00	0.000
3+2+1	0.00040	0.000	0.000	0.510	19.302	2.28a	0.32s	0.00	0.000
-------------- 3-division damage:				0.013	Probability of damage: 0.018				-----
6+5+4+3	0.00068	0.000	0.000	0.510	8.552	3.24f	0.97s	0.00	0.000
5+4+3+2	0.00000	0.000	0.000	0.510	13.570	1.61f	0.43s	0.00	0.000
4+3+2+1	0.00000	0.000	0.000	0.510	18.404	0.88a	0.27s	0.00	0.000
-------------- 4-division damage:				0.000	Probability of damage: 0.001				-----

Attained index in this condition: 0.510 Total probability of damage: 0.953
Required index: 0.608
Distances in METERS.--Angles in deg.

Tablica 33. Rezultati MSC.216(82) vjerojatnosne metode, d_P vodna linija, FLOOD kritične točke

PARTIAL SUBDIVISION DRAUGHT: REDUCED HOMOGENOUS LOADED, 100% STORES
T=7.7884 m

PERMEABILITY SETTINGS

Name	Description	Perm.	Cubic METERS
HOLD_4.C		0.9000*	3,628.047
HOLD_3.C		0.9000*	12,919.311
HOLD_2.C		0.9000*	12,551.093
HOLD_1.C		0.9000*	4,843.752

------------------* Permeability override-------------------

PROBABILISTIC DAMAGE STABILITY MSC.216(82)
Cargo Vessel Version
Subdivision length: 174.350 Terminals: 170.450f, 3.900a
Breadth: 31.132 Draft: 7.776

Divisions	P	Smin	P*S*V	A	Depth	Trim	Heel	Range	MaxRA
None	0.00000	1.000	0.000	0.000	9.227	1.00a	1.96s	26.35	0.917
6	0.01486	1.000	0.015	0.015	9.254	1.03a	1.94s	26.22	0.925
5	0.02216	1.000	0.022	0.037	9.236	1.02a	1.95s	26.36	0.931
4	0.08803	1.000	0.088	0.125	8.550	0.19a	2.70s	23.06	0.854
3	0.16707	0.998	0.167	0.292	8.893	0.80f	3.06s	15.86	0.712
2	0.16707	0.869	0.145	0.437	12.229	1.61a	1.34s	9.14	0.650
1	0.21022	0.852	0.179	0.616	12.175	2.66a	1.54s	8.44	0.321
-------------- 1-division damage:				0.616	Probability of damage: 0.669				-----
6+5	0.02620	1.000	0.026	0.642	9.267	1.05a	1.93s	26.22	0.938
5+4	0.04256	1.000	0.043	0.685	8.432	0.07a	2.78s	22.35	0.862
4+3	0.06270	0.000	0.000	0.685	7.535	2.94f	2.11s	0.00	0.000
3+2	0.06654	0.762	0.051	0.736	13.154	0.25f	1.23s	5.39	0.592
2+1	0.06682	0.000	0.000	0.736	18.318	4.66a	0.49s	0.00	0.000
-------------- 2-division damage:				0.119	Probability of damage: 0.265				-----
6+5+4	0.01333	1.000	0.013	0.749	8.445	0.08a	2.77s	22.34	0.869
5+4+3	0.00353	0.000	0.000	0.749	7.204	3.34f	1.37s	0.00	0.000
4+3+2	0.00040	0.000	0.000	0.749	12.644	1.61f	0.41s	0.00	0.000
3+2+1	0.00040	0.000	0.000	0.749	18.374	2.21a	0.26s	0.00	0.000
-------------- 3-division damage:				0.013	Probability of damage: 0.018				-----
6+5+4+3	0.00068	0.000	0.000	0.749	6.902	3.64f	1.15s	0.00	0.000
5+4+3+2	0.00000	0.000	0.000	0.749	12.454	1.84f	0.39s	0.00	0.000
4+3+2+1	0.00000	0.000	0.000	0.749	17.413	0.71a	0.20s	0.00	0.000
-------------- 4-division damage:				0.000	Probability of damage: 0.001				-----

Attained index in this condition: 0.749 Total probability of damage: 0.953
Required index: 0.608
Distances in METERS.---Angles in deg.

Tablica 34. Rezultati MSC.216(82) vjerojatnosne metode, d_L vodna linija, FLOOD kritične točke

```
LOWEST SUBDIVISION DRAUGHT: BALLAST LOADED, 10% STORES
                      T=6.346 m


                        PERMEABILITY SETTINGS
        Name          Description           Perm.     Cubic METERS
        ------------------------------------------------------------
        HOLD_4.C                            0.9500       3,829.605
        HOLD_3.C                            0.9500      13,637.051
        HOLD_2.C                            0.9500      13,248.375
        HOLD_1.C                            0.9500       5,112.850
        ------------------------------------------------------------


               PROBABILISTIC DAMAGE STABILITY MSC.216(82)
                          Cargo Vessel Version
         Subdivision length: 174.350   Terminals: 170.450f, 3.900a
                      Breadth: 31.132   Draft: 6.332

Divisions-------P------Smin--P*S*V----A-----Depth--Trim----Heel---Range--MaxRA
None          0.00000  1.000  0.000  0.000   7.785  1.00a   1.96s  33.64  1.004
6             0.01486  1.000  0.015  0.015   7.889  1.10a   1.96s  33.65  1.020
5             0.02216  1.000  0.022  0.037   7.918  1.13a   1.95s  33.65  1.032
4             0.08803  1.000  0.088  0.125   7.292  0.50a   2.25s  30.53  0.928
3             0.16707  0.987  0.165  0.290   7.045  0.65f  10.69s  15.16  0.787
2             0.16707  1.000  0.167  0.457  10.934  1.86a   1.03s  16.98  0.933
1             0.21022  1.000  0.210  0.667  10.326  2.41a   1.19s  17.41  0.924
-------------- 1-division damage:   0.667  Probability of damage: 0.669  -----

6+5           0.02620  1.000  0.026  0.693   8.041  1.25a   1.94s  33.19  1.050
5+4           0.04256  1.000  0.043  0.736   7.419  0.62a   2.24s  30.84  0.956
4+3           0.06270  0.000  0.000  0.736   5.335  3.44f   4.66s   0.00  0.000
3+2           0.06654  0.915  0.061  0.797  11.697  0.30f   1.08s  11.21  1.065
2+1           0.06682  0.000  0.000  0.797  17.739  5.21a   0.28s   0.00  0.000
-------------- 2-division damage:   0.130  Probability of damage: 0.265  -----

6+5+4         0.01333  1.000  0.013  0.810   7.551  0.74a   2.23s  31.18  0.974
5+4+3         0.00353  0.000  0.000  0.810   4.825  4.06f   1.87s   0.00  0.000
4+3+2         0.00040  0.000  0.000  0.810  11.331  1.98f   0.38s   0.00  0.000
3+2+1         0.00040  0.000  0.000  0.810  18.002  2.43a   0.14s   0.00  0.000
-------------- 3-division damage:   0.013  Probability of damage: 0.018  -----

6+5+4+3       0.00068  0.000  0.000  0.810   4.447  4.44f   1.24s   0.00  0.000
5+4+3+2       0.00000  0.000  0.000  0.810  11.168  2.20f   0.35s   0.00  0.000
4+3+2+1       0.00000  0.000  0.000  0.810  16.912  0.66a   0.08s   0.00  0.000
-------------- 4-division damage:   0.000  Probability of damage: 0.001  -----

Attained index in this condition:   0.810  Total probability of damage: 0.953
Required index:                     0.608
Distances in METERS.-------------------------------------------Angles in deg.
```

8. ZAKLJUČAK

U ovom radu je modeliran brod za prijevoz tereta na kotačima, te je koristeći program GHS izvršen proračun stabiliteta oštećenog broda vjerojatnosnom metodom. Također je za isti model izvršen proračun stabiliteta u oštećenom stanju determinističkom metodom oštećivanja, prvo jednog po jednog tanka, potom po dva susjedna i na kraju po tri susjedna tanka. Modelom su u vjerojatnosnom proračunu obuhvaćena tri stanja krcanja broda, kako je definirano u pravilima [9], dok je model u determinističkom proračunu definiran s dva početna stanja krcanja procijenjena kao granična. Svako od tih početnih stanja oštećeno je s 27 različitih slučajeva oštećenja. Rezultat vjerojatnosnog proračuna je indeks pregrađivanja *A*, dok je rezultat determinističkog proračuna predstavljen s prikazom oštećenih prostora i krivuljom stabiliteta te uzdužne čvrstoće. Dobiveni rezultati uspoređeni su s propisima [9] i rezultatima za neoštećeno stanje. Pokazalo se da brod u svim stanjima oštećenja zadovoljava kriterije stabiliteta po determinističkoj metodi. Rezultati vjerojatnosne analize uspoređeni su s rezultatima izrađenim prema prethodnim pravilima [4] te je zaključak da je novi kriterij, donesen 2008. godine povećao zahtijevani indeks pregrađivanja *R*. Usprkos tome, dobiveni indeks *A* je veći od zahtijevanog indeksa *R*.

Iz rezultata vjerojatnosne metode [Tablica 24. i Slika 28.] vidljivo je također da je brod zadovoljio zahtijevani indeks pregrađivanja *R* uzevši u obzir i zanemarivanje nepropusnosti na vremenske uvijete nekih od kritičnih točaka.

Oštećivanje po determinističkoj metodi daje realniji uvid što se s brodom događa u slučaju oštećenja jer imamo stvarno stanje što je pouzdanija mjera sigurnosti u odnosu na vjerojatnosnu metodu.

Ono što se može navesti kao nedostatak vjerojatnosne metode bilo bi slijedeće:

- Nedovoljno točno određena funkcija razdiobe vjerojatnosti s obzirom na trenutno dostupnu statistiku o oštećenjima jer ova statistika uzima u obzir brodove koji su potonuli, a ne i ostale slučajeve kod kojih su brodovi bili lakše oštećeni.
- Realni kriterij za vjerojatnost preživljavanja oštećenja, jer neka stanja oštećenja koja ispadaju kritična primjenom ove metode nisu kritična u stvarnosti za brod.

- Određivanje realnih stanja krcanja jer je fiktivno stanje krcanjai dalje prisutno u novim pravilima (d_P) zbog primjene statistike u metodi.
- Pravilan opis otvora i točki progresivnog naplavljivanja i cjevovoda za sprječavanje nesimetrične naplave. Indeks pregrađivanja treba biti jednak za dani brod bez obzira kojim ga programom proračunavamo i u kojem projektnom uredu.
- Određivanje realnih koeficijenata naplavljivosti pojedinih prostora.

Vjerojatnosna metoda je ušla kao takva u nova harmonizirana pravila za proračun stabiliteta u oštećenom stanju zbog matematičkog modeliranja cijelog procesa te kao takva daje jednu prividnu sigurnost u dobivenim rezultatima s tim da treba biti oprezan s obzirom na gore navedene nedostatke uzimajući u obzir razne konfiguracije brodova i njihove veličine [11] [12].

9. LITERATURA

[1] http://www.imo.org/Pages/home.aspx , 13.05.2015.

[2] IMO rezolucija A.265 (VIII), Regulations on Subdivision and Stability of Passenger Ships as Equivalent to Part B of Chapter II of International Convention for the Safety of Life at Sea, 1939., London, 1974.

[3] IMO rezolucija MSC.19(58), Resolution on the adoption of amendments to the 1974 SOLAS Convention regarding subdivision and damage stability of dry cargo ships, London, 1990.

[4] IMO rezolucija A.684(17), Explanatory notes to the SOLAS regulations on subdivision and damage stability of cargo ships of 100 m in length and over, IMO London, 1993.

[5] IMO rezolucija MSC.216(82), Adoption of Amendments to the International Convention for the Safety of Lifea at Sea, 1974, as amended

[6] IMO rezolucija MSC.281(85), Explanatory notes to the SOLAS chapter II-1 Subdivision and Damage Stability regulations

[7] https://www.fleetmon.com/ , 10.05.2015.

[8] Programski paket GHS, verzija 14.00

[9] Bureau Veritas, Classification rules, Pt. B, Ch. 3, Sec. 3;Pt B, Ch. 3, App. 3; 13.05.2015.

[10] Uršić, J.: Stabilitet broda, Sveučilište u Zagrebu, Fakultet strojarstva i brodogradnje, Zagreb, 2005.

[11] Giorgio Trincas.: SHIP DESIGN, A Rational Approach, Part II, University of Trieste, Faculty of Engineering, Department of Naval Architecture, Ocean and Environmental Engineering, Trieste, 2010.

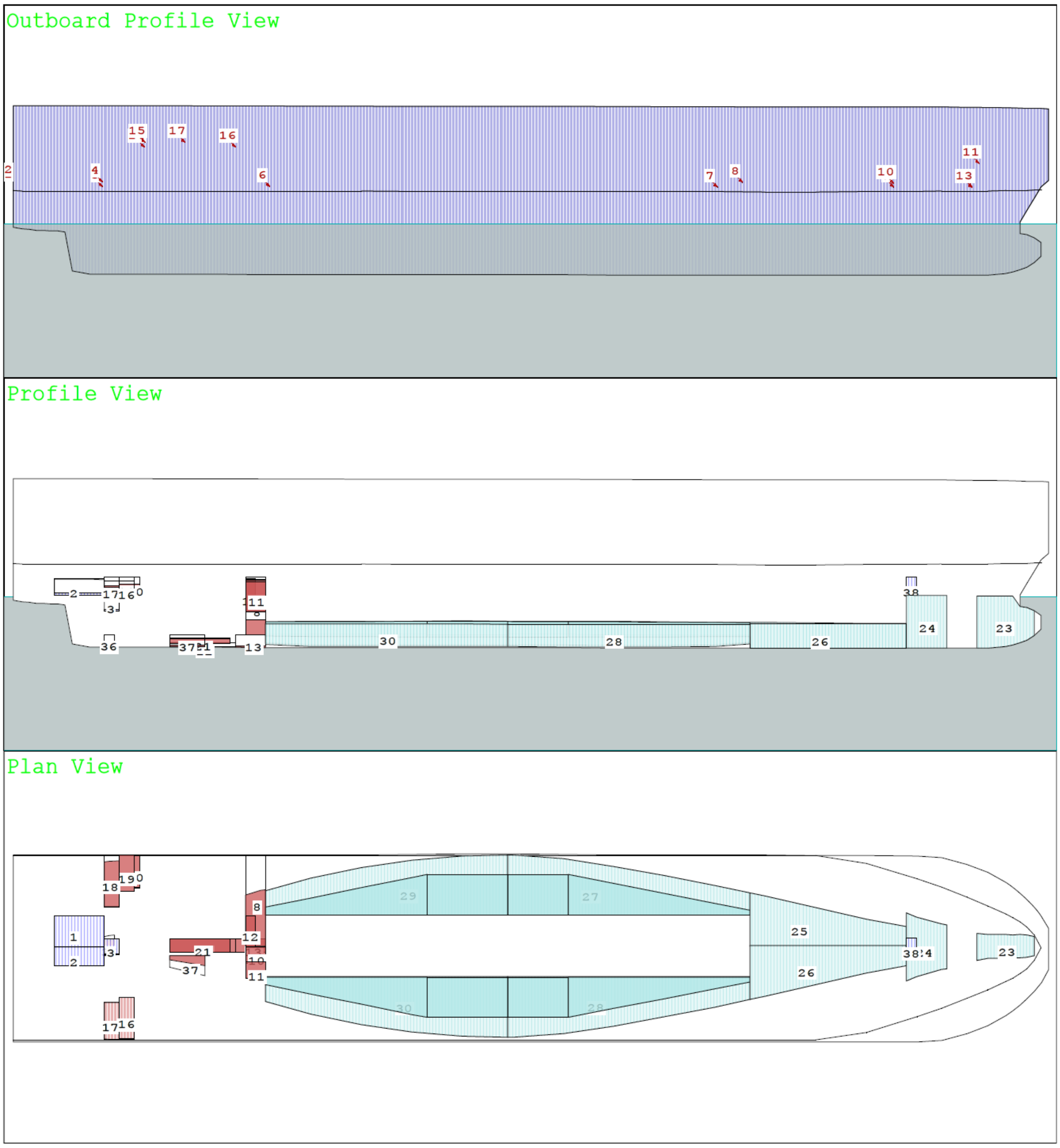
[12] EMSA (European Maritime Safety Agency – Europska Agencija za Pomorsku Sigurnost).: Research for the Parameters of the Damage Stability Rules including the Calculation of Water on Deck of Ro-Ro Passenger Vessels, for the amendment of the Directives 2003/25/EC and 98/18/EC, Final Report Part I, Hamburgische Schiffbau-Versuchsanstalt GMBH, Hamburg, 2009.

PRILOZI

i. Stanje krcanja 1 – homogeno sa 10% zaliha

LOAD CONDITION 01: HOMOGENOUS LOADED, T=8,440 m, 10% STORES

CG - Draft: 8.531 @ 0.000 Trim: fwd 0.23/165.00 Heel: stbd 1.49 deg.



Slika 29. Stanje krcanja 1 – prikaz tankova i kritičnih točaka

Tablica 35. Stanje krcanja 1 – homogeno sa 10% zaliha, neoštećeno

```
LOAD CONDITION 01: HOMOGENOUS LOADED, T=8,440 m, 10% STORES


              WEIGHT and DISPLACEMENT and CRITICAL POINT STATUS
                       Baseline draft: 8.531 @ Origin
                 Trim: Fwd 0.23/165.00,  Heel: Stbd 1.49 deg.
Part------------------------------Weight(MT)----LCG-----TCG-----VCG
LIGHT SHIP                         13,035.13  76.190f  0.039s 14.899
hold_1.c                            1,516.98 140.325f  0.000  19.760
hold_2.c                            2,336.74  99.800f  0.000  15.690
hold_3.c                            2,309.20  59.000f  0.000  15.680
hold_4.c                            1,363.76  16.983f  0.000  20.760
CREW & EFFECTS                          2.50 128.275f  0.000  29.300
PROVIANT                                2.00 120.625f  0.000  29.200
  Total Fixed--------->            20,566.31  77.758f  0.025s 15.827
                Load-----SpGr-----Weight(MT)----LCG-----TCG-----VCG-------FSM
FW_TANK.P      0.060    1.000           6.54   7.254f  2.242p  8.893       96.3
FW_TANK.S      0.150    1.000           9.73   7.221f  1.617s  9.006       20.3
FW_FEED_TANK.C 0.070    1.000           1.12  12.679f  0.073s  6.263        3.2
HFO_TANK.P     0.210    0.960          61.32  36.933f  4.024p  3.346      196.9
HFO_SETT_1.S   1.000    0.960          42.65  36.900f  1.312s  8.790        0.0
HFO_SETT_2.S   0.950    0.960          40.52  36.900f  3.941s  8.659        4.7
HFO_DAILYTNK.P 1.000    0.960          42.65  36.050f  2.625p  8.790        0.0
HFO_OVERFLOW.C 0.090    0.960           1.94  36.053f  0.059s  0.114        4.4
DO_DAILY_1.S   0.340    0.860          10.13  15.254f 10.800s  9.560       55.3
DO_DAILY_2.S   0.420    0.860          10.09  12.696f 11.693s  9.851       41.2
LO_MECYL_OIL.P 0.370    0.900          15.03  12.701f  9.338p  9.495       80.9
LO_MEOILSTOR.P 0.420    0.900          10.88  15.248f 11.461p  9.777       42.3
LO_AUXOILSTR.P 0.390    0.900           3.00  16.927f 11.815p  9.763        9.8
LO_MEOILCIRC.C 0.760    0.900          12.45  27.569f  0.017s  1.018        8.3
LO_REN_TANK.C  0.140    0.900           2.03  27.985f  0.115s  0.066        9.0
SW_FOREPEAK.C  1.000    1.025         179.29 162.555f  0.000   4.698        0.0
SW_DEEPTANK.C  1.000    1.025         310.36 149.709f  0.000   5.429        0.0
SW_DB_TANK_1.P 1.000    1.025         439.28 130.905f  2.554p  2.437        0.0
SW_DB_TANK_1.S 1.000    1.025         439.28 130.905f  2.554s  2.437        0.0
SW_DB_TANK_2.P 1.000    1.025         474.28  96.332f  9.180p  2.075        0.0
SW_DB_TANK_2.S 1.000    1.025         474.28  96.332f  9.180s  2.075        0.0
SW_DB_TANK_3.P 1.000    1.025         516.39  62.041f  9.436p  2.058        0.0
SW_DB_TANK_3.S 1.000    1.025         516.39  62.041f  9.436s  2.058        0.0
STERN_OIL_DR.C 0.090    0.924           0.73  12.258f  0.028s  0.227        0.8
OIL_DR_TANK.S  0.090    0.924           1.66  25.946f  2.196s  0.329        0.9
SEWAGE_TANK.C  1.000    1.000          15.21 147.400f  0.000  10.380        0.0
  Total Tanks--------->             3,637.22  98.021f  0.058p  2.988      574.3
  Total Weight-------->            24,203.53  80.803f  0.012s 13.897
                                    Displ(MT)----LCB-----TCB-----VCB
HULL                    1.025      24,203.52  80.816f  0.247s  4.894
------------------------------------------------------------------------------
              Righting Arms:                 0.000   0.000s
Distances in METERS.-----------------------------------------Moments in m.-MT.
```

Tablica 36. Stanje krcanja 1 – kritične točke, hidrostatičke karakteristike i poluga stabiliteta

```
LOAD CONDITION 01: HOMOGENOUS LOADED, T=8,440 m, 10% STORES


      Critical Points----------------------LCP-----TCP-----VCP-----Height
  (1) AirPipe AP SB           TIGHT   9.900a 15.100s 15.260      6.347
  (2) AirPipe AP PS           TIGHT   9.900a 15.100p 15.260      7.134
  (3) AirPipe FreshW SB       TIGHT  11.110f 15.100s 15.260      6.317
  (4) AirPipe FreshW PS       TIGHT  11.110f 15.100p 15.260      7.104
  (5) AirPipe DB 3 SB         TIGHT  39.250f 15.130s 15.260      6.277
  (6) AirPipe DB 3 PS         TIGHT  39.250f 15.130s 15.260      6.277
  (7) AirPipe DB 2 SB         TIGHT 114.680f 14.950s 15.260      6.174
  (8) AirPipe DB 2 PS         TIGHT 118.920f 14.950p 15.260      6.946
  (9) AirPipe DB 1 SB         TIGHT 144.400f 12.060s 15.260      6.207
 (10) AirPipe DB 1 PS         TIGHT 144.400f 12.060p 15.260      6.835
 (11) AirPipe FP              TIGHT 158.750f 10.150p 18.710     10.214
 (12) Weath Door Domest       TIGHT 157.650f  0.600p 14.910      6.168
 (13) Weath Door Bosuns       TIGHT 157.650f  1.400s 14.910      6.116
 (14) ER Vent 1 SP            FLOOD  18.200f 15.550s 21.910     12.943
 (15) ER Vent 1 PS            FLOOD  18.200f 15.550p 21.910     13.753
 (16) ER Vent 2 SB            FLOOD  33.500f 15.550s 21.910     12.922
 (17) ER Vent 2 PS            FLOOD  25.000f 15.550p 21.910     13.743
   Distances in METERS.--------------------------------------------------

                       HYDROSTATIC PROPERTIES
             Trim: Fwd 0.23/165.00, Heel: Stbd 1.49 deg.

Origin  Displacement     Center of Buoyancy
 Depth----Weight(MT)----LCB-----TCB-----VCB-----WPA-----LCF------BML-----BMT
 8.528    24,203.52  80.816f  0.247s  4.894  3788.4  75.583f  249.91   9.466
Distances in METERS.----Specific Gravity = 1.025.---True Free Surface included.


                     RIGHTING ARMS vs HEEL ANGLE
      Total CG:  LCG = 80.803f  TCG = 0.012s  VCG = 13.897
                        Free Surface Adjustment:   0.024
   Adjusted CG:  LCG = 80.803f  TCG = 0.012s  VCG = 13.921

 Origin    Degrees of   Displacement    Righting Arms          Flood Pt
  Depth---Trim----Heel----Weight(MT)---in Trim--in Heel---> Area--Height
  8.528   0.08f   1.49s      24,203     0.000    0.000    0.0000   6.115(13)
  8.461   0.10f   3.99s      24,204     0.000    0.025    0.0005  12.252(16)
  8.316   0.16f   6.49s      24,203     0.000    0.067    0.0025  11.604(16)
  8.105   0.23f   8.99s      24,203     0.000    0.127    0.0066  10.970(16)
  7.865   0.31f  11.49s      24,202     0.000    0.191    0.0135  10.328(16)
  7.604   0.38f  13.99s      24,202     0.002a   0.259    0.0233   9.674(16)
  7.324   0.45f  16.49s      24,202     0.002a   0.333    0.0363   9.009(16)
  7.025   0.51f  18.99s      24,203     0.000    0.414    0.0525   8.334(16)
  6.826   0.54f  20.58s      24,203     0.000    0.469    0.0648 Dk/MargImm.
  6.709   0.56f  21.49s      24,203     0.000    0.502    0.0725   7.650(16)
  6.375   0.61f  23.99s      24,203     0.000    0.596    0.0964   6.961(16)
  6.224   0.63f  25.08s      24,203     0.000    0.638    0.1082  -0.002(7)
  6.022   0.65f  26.49s      24,203     0.000    0.693    0.1245   6.268(16)
  5.650   0.69f  28.99s      24,203     0.000    0.796    0.1570   5.574(16)
```

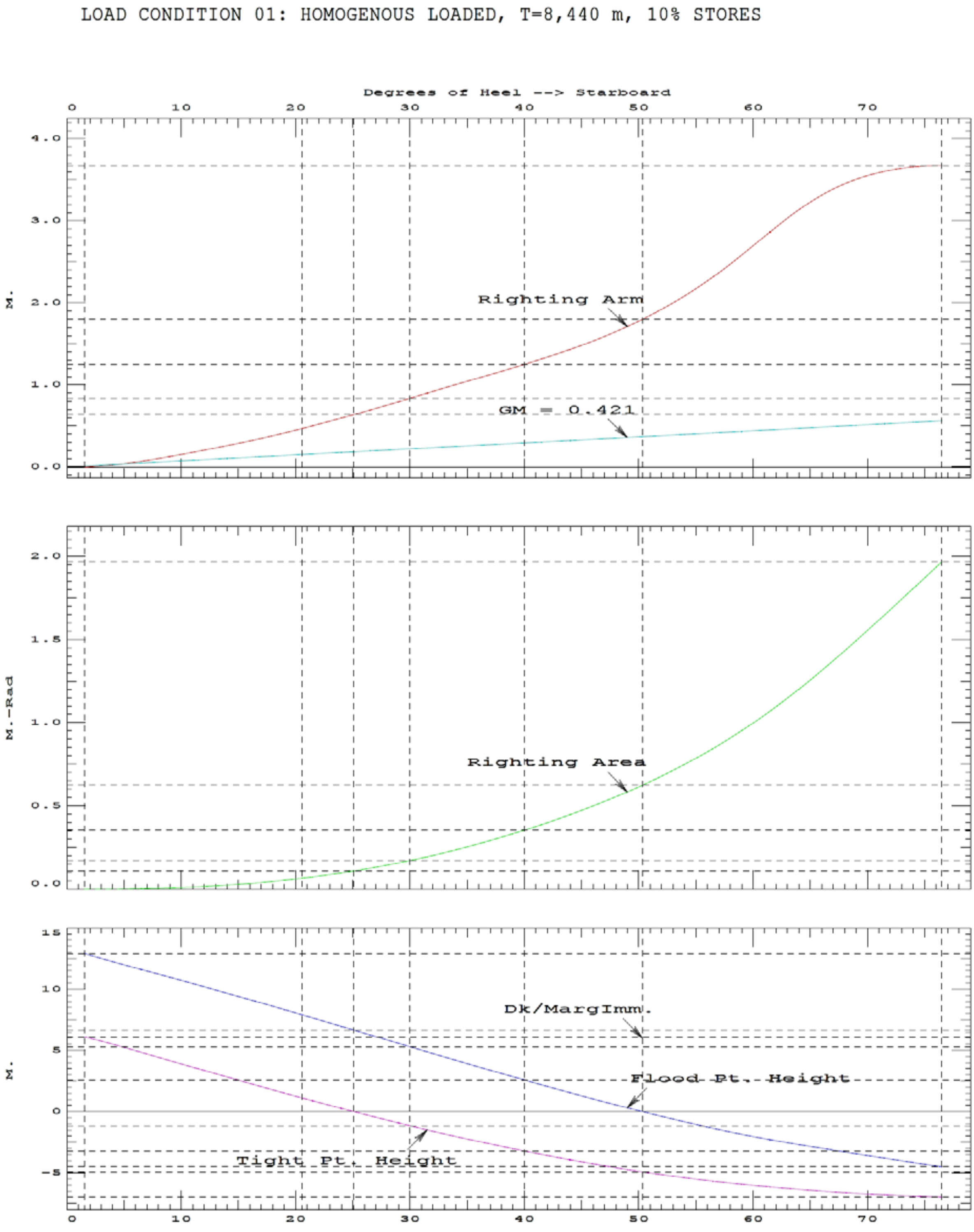
Tablica 37. Stanje krcanja 1 – kriteriji stabiliteta u neoštećenom stanju

LOAD CONDITION 01: HOMOGENOUS LOADED, T=8,440 m, 10% STORES

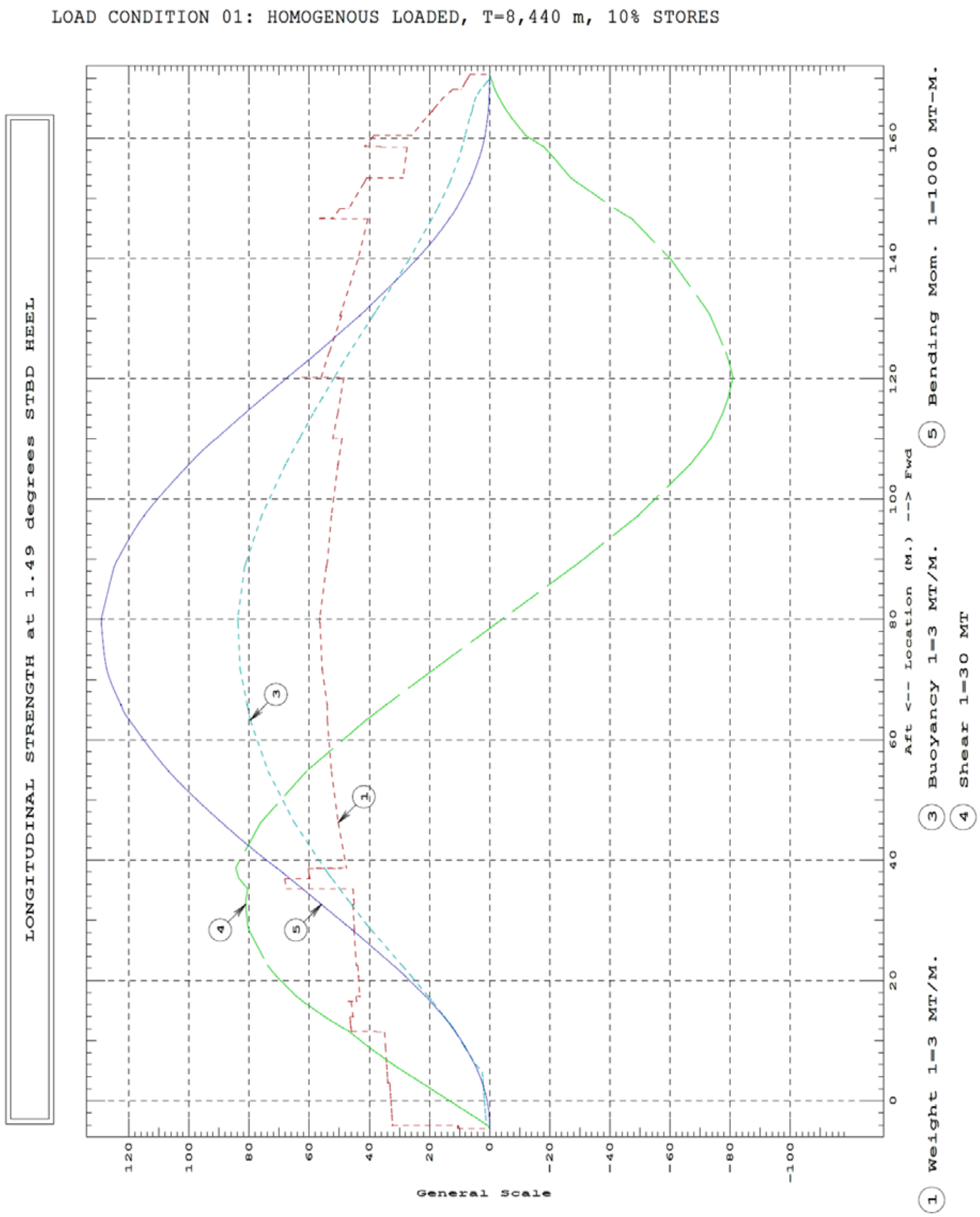
5.259	0.72f	31.49s	24,203	0.000	0.900	0.1940	4.882(16)
4.848	0.74f	33.99s	24,203	0.000	1.004	0.2355	4.194(16)
4.410	0.75f	36.49s	24,203	0.000	1.104	0.2815	3.515(16)
3.951	0.77f	38.99s	24,203	0.000	1.208	0.3319	2.846(16)
3.467	0.77f	41.49s	24,204	0.000	1.315	0.3869	2.188(16)
2.959	0.78f	43.99s	24,204	0.000	1.432	0.4468	1.546(16)
2.425	0.79f	46.49s	24,204	0.000	1.562	0.5121	0.919(16)
1.864	0.80f	48.99s	24,204	0.000	1.711	0.5835	0.313(16)
1.555	0.80f	50.32s	24,203	0.003a	1.799	0.6242	-0.000(16)
1.275	0.80f	51.49s	24,204	0.000	1.883	0.6619	-0.271(16)
0.658	0.81f	53.99s	24,203	0.000	2.083	0.7483	-0.829(16)
0.008	0.82f	56.49s	24,203	0.000	2.315	0.8441	-1.356(16)
-0.681	0.83f	58.99s	24,203	0.000	2.582	0.9509	-1.845(16)
-1.418	0.86f	61.49s	24,203	0.000	2.866	1.0697	-2.291(16)
-2.201	0.90f	63.99s	24,203	0.000	3.134	1.2006	-2.695(16)
-3.010	0.96f	66.49s	24,202	0.000	3.352	1.3423	-3.070(16)
-3.802	1.00f	68.99s	24,202	0.002a	3.504	1.4921	-3.441(16)
-4.581	1.02f	71.49s	24,203	0.000	3.603	1.6473	-3.805(16)
-5.354	1.04f	73.99s	24,204	0.000	3.658	1.8057	-4.159(16)
-6.119	1.06f	76.49s	24,204	0.003f	3.674	1.9657	-4.500(16)

```
 Distances in METERS.----Specific Gravity = 1.025.-----------Area in m.-Rad.

           Critical Points----------------------LCP-----TCP-----VCP
       (7) AirPipe DB 2 SB           TIGHT 114.680f 14.950s 15.260
      (13) Weath Door Bosuns         TIGHT 157.650f  1.400s 14.910
      (16) ER Vent 2 SB              FLOOD  33.500f 15.550s 21.910
LIM---------------IMO A.167 STABILITY CRITERION-------Min/Max--------Attained
(1)  GM Upright                                >    0.150   m.    0.421 P
(2) Area from abs 1.492 deg to 30              >   0.0550 m.-Rad 0.1940 P
(3) Area from abs 1.492 deg to 40 or Flood     >   0.0900 m.-Rad 0.3869 P
(4) Area from 30 deg to 40 or Flood            >   0.0300 m.-Rad 0.1930 P
(5) Righting Arm at 30 deg                     >    0.200   m.    0.900 P
(6) Absolute Angle at MaxRA                    >    25.00  deg    76.49 P
--------------------Relative angles measured from 1.492s---------------------
```



Slika 30. Stanje krcanja 1 – karakteristike stabiliteta

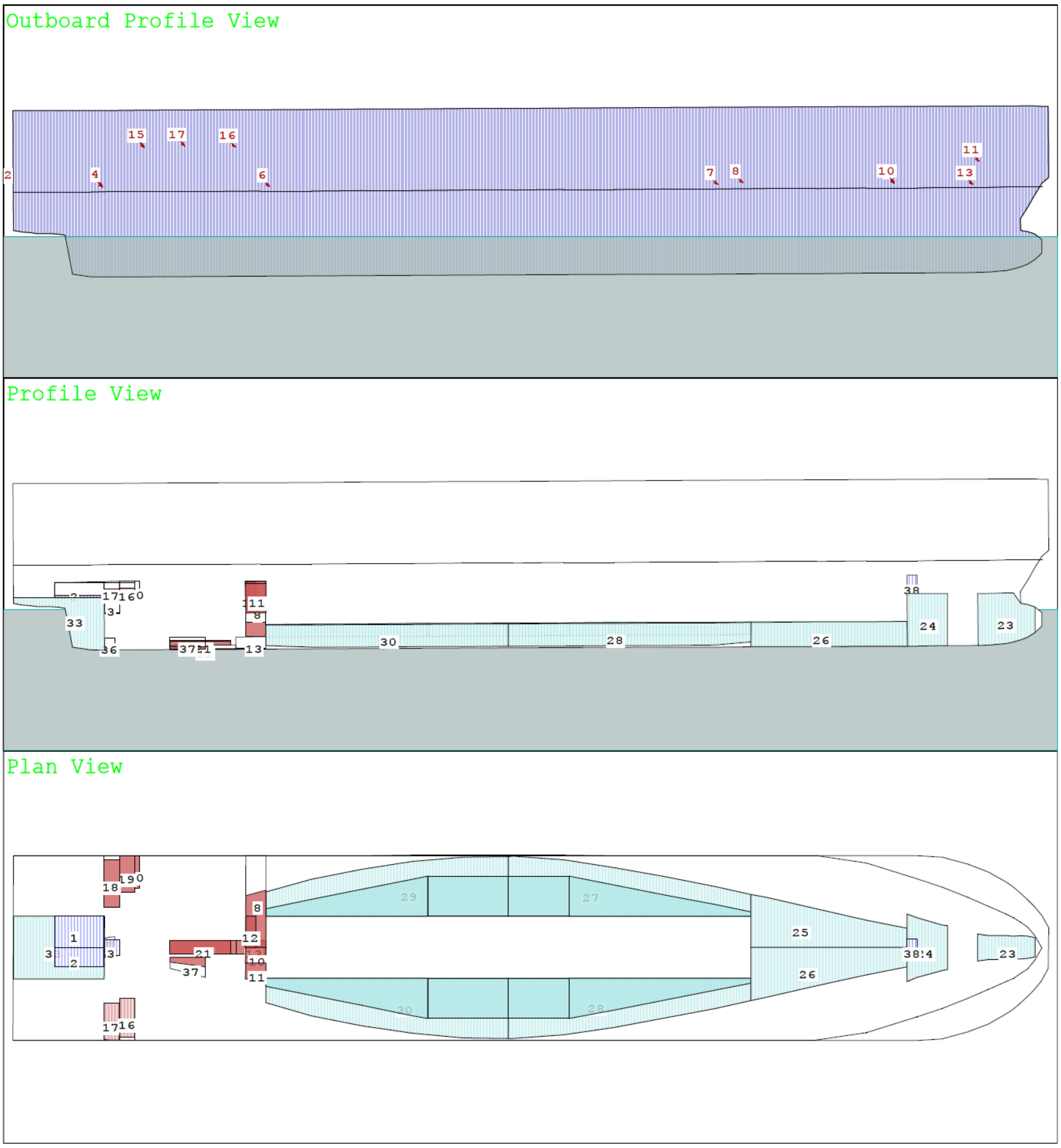


Slika 31. Stanje krcanja 1 – karakteristike uzdužne čvrstoće

ii. Stanje krcanja 2 – balastno sa 10% zaliha

LOAD CONDITION 02: BALAST LOADED, T = 6,346 m, 10% STORES

CG - Draft: 6.792 @ 0.000 Trim: aft 0.82/165.00 Heel: stbd 0.38 deg.



Slika 32. Stanje krcanja 2 – prikaz tankova i kritičnih točaka

Tablica 38. Stanje krcanja 2 – homogeno sa 10% zaliha, neoštećeno

```
LOAD CONDITION 02: BALAST LOADED, T = 6,346 m, 10% STORES


              WEIGHT and DISPLACEMENT and CRITICAL POINT STATUS
                       Baseline draft: 6.792 @ Origin
                 Trim: Aft 0.82/165.00,  Heel: Stbd 0.38 deg.
Part----------------------------------Weight(MT)----LCG-----TCG-----VCG
LIGHT SHIP                            12,455.65  76.087f  0.040s 14.838
CREW & EFFECTS                             2.50 128.275f  0.000  29.300
PROVIANT                                   2.00 120.625f  0.000  29.200
  Total Fixed--------->               12,460.15  76.105f  0.040s 14.843
                Load-----SpGr-----Weight(MT)----LCG-----TCG-----VCG-------FSM
FW_TANK.P      0.060    1.000           6.54   7.013f  2.527p  8.889      96.2
FW_TANK.S      0.150    1.000           9.73   7.125f  1.576s  9.005      20.3
FW_FEED_TANK.C 0.070    1.000           1.12  12.660f  0.019s  6.263       3.2
HFO_TANK.P     0.210    0.960          61.32  36.931f  4.087p  3.345     201.6
HFO_SETT_1.S   1.000    0.960          42.65  36.900f  1.312s  8.790       0.0
HFO_SETT_2.S   0.950    0.960          40.52  36.899f  3.938s  8.659       4.7
HFO_DAILYTNK.P 1.000    0.960          42.65  36.050f  2.625p  8.790       0.0
HFO_OVERFLOW.C 0.090    0.960           1.94  35.978f  0.015s  0.114       4.4
DO_DAILY_1.S   0.340    0.860          10.13  15.250f 10.701s  9.558      48.4
DO_DAILY_2.S   0.420    0.860          10.08  12.691f 11.613s  9.850      41.0
LO_MECYL_OIL.P 0.370    0.900          15.03  12.697f  9.450p  9.493      92.0
LO_MEOILSTOR.P 0.420    0.900          10.88  15.243f 11.537p  9.776      42.3
LO_AUXOILSTR.P 0.390    0.900           3.00  16.927f 11.881p  9.762      10.4
LO_MEOILCIRC.C 0.760    0.900          12.45  27.482f  0.004s  1.017       8.3
LO_REN_TANK.C  0.140    0.900           2.03  27.304f  0.030s  0.066       9.0
SW_FOREPEAK.C  1.000    1.025         179.29 162.555f  0.000   4.698       0.0
SW_DEEPTANK.C  1.000    1.025         310.36 149.709f  0.000   5.429       0.0
SW_DB_TANK_1.P 1.000    1.025         439.28 130.905f  2.554p  2.437       0.0
SW_DB_TANK_1.S 1.000    1.025         439.28 130.905f  2.554s  2.437       0.0
SW_DB_TANK_2.P 1.000    1.025         474.28  96.332f  9.180p  2.075       0.0
SW_DB_TANK_2.S 1.000    1.025         474.28  96.332f  9.180s  2.075       0.0
SW_DB_TANK_3.P 1.000    1.025         516.39  62.041f  9.436p  2.058       0.0
SW_DB_TANK_3.S 1.000    1.025         516.39  62.041f  9.436s  2.058       0.0
SW_AFTERPEAK.C 1.000    1.025         216.70   6.223f  0.000   6.759       0.0
STERN_OIL_DR.C 0.090    0.924           0.73  12.252f  0.007s  0.227       0.8
OIL_DR_TANK.S  0.090    0.924           1.66  25.871f  2.177s  0.333       0.8
SEWAGE_TANK.C  1.000    1.000          15.21 147.400f  0.000  10.380       0.0
  Total Tanks--------->                3,853.92  92.858f  0.058p  3.200     583.2
  Total Weight-------->               16,314.07  80.062f  0.017s 12.093
                                        Displ(MT)----LCB-----TCB-----VCB
HULL                    1.025         16,314.15  80.020f  0.073s  3.604
------------------------------------------------------------------------------
               Righting Arms:                     0.000   0.000s
Distances in METERS.-----------------------------------------Moments in m.-MT.
```

Tablica 39. Stanje krcanja 2 – kritične točke, hidrostatičke karakteristike i poluga stabiliteta

LOAD CONDITION 02: BALAST LOADED, T = 6,346 m, 10% STORES

	Critical Points		LCP	TCP	VCP	Height
(1)	AirPipe AP SB	TIGHT	9.900a	15.100s	15.260	8.319
(2)	AirPipe AP PS	TIGHT	9.900a	15.100p	15.260	8.519
(3)	AirPipe FreshW SB	TIGHT	11.110f	15.100s	15.260	8.423
(4)	AirPipe FreshW PS	TIGHT	11.110f	15.100p	15.260	8.623
(5)	AirPipe DB 3 SB	TIGHT	39.250f	15.130s	15.260	8.563
(6)	AirPipe DB 3 PS	TIGHT	39.250f	15.130s	15.260	8.563
(7)	AirPipe DB 2 SB	TIGHT	114.680f	14.950s	15.260	8.939
(8)	AirPipe DB 2 PS	TIGHT	118.920f	14.950p	15.260	9.158
(9)	AirPipe DB 1 SB	TIGHT	144.400f	12.060s	15.260	9.106
(10)	AirPipe DB 1 PS	TIGHT	144.400f	12.060p	15.260	9.266
(11)	AirPipe FP	TIGHT	158.750f	10.150p	18.710	12.774
(12)	Weath Door Domest	TIGHT	157.650f	0.600p	14.910	8.906
(13)	Weath Door Bosuns	TIGHT	157.650f	1.400s	14.910	8.892
(14)	ER Vent 1 SP	FLOOD	18.200f	15.550s	21.910	15.105
(15)	ER Vent 1 PS	FLOOD	18.200f	15.550p	21.910	15.311
(16)	ER Vent 2 SB	FLOOD	33.500f	15.550s	21.910	15.181
(17)	ER Vent 2 PS	FLOOD	25.000f	15.550p	21.910	15.345

Distances in METERS.

HYDROSTATIC PROPERTIES

Trim: Aft 0.82/165.00, Heel: Stbd 0.38 deg.

Origin Depth	Displacement Weight (MT)	LCB	TCB	VCB	WPA	LCF	BML	BMT
6.792	16,314.15	80.020f	0.073s	3.604	3180.5	80.950f	243.13	10.990

(Center of Buoyancy: LCB, TCB, VCB)

Distances in METERS.----Specific Gravity = 1.025.---True Free Surface included.

RIGHTING ARMS vs HEEL ANGLE

Total CG: LCG = 80.062f TCG = 0.017s VCG = 12.093

Free Surface Adjustment: 0.036

Adjusted CG: LCG = 80.063f TCG = 0.017s VCG = 12.128

Origin Depth	Degrees of Trim	Degrees of Heel	Displacement Weight (MT)	Righting Arms in Trim	Righting Arms in Heel	Area	Flood Pt Height
6.792	0.28a	0.38s	16,314	0.000	0.000	0.0000	8.319(1)
6.772	0.28a	2.88s	16,314	0.000	0.110	0.0024	14.418(14)
6.723	0.27a	5.38s	16,314	0.000	0.224	0.0097	13.719(14)
6.641	0.26a	7.88s	16,314	0.000	0.340	0.0220	13.012(14)
6.524	0.23a	10.38s	16,314	0.000	0.463	0.0395	12.301(14)
6.363	0.20a	12.88s	16,314	0.002a	0.598	0.0626	11.593(14)
6.111	0.12a	15.38s	16,314	0.000	0.765	0.0923	10.930(14)
5.794	0.03a	17.88s	16,314	0.000	0.947	0.1296	10.293(14)
5.448	0.07f	20.38s	16,314	0.000	1.127	0.1749	9.634(16)
5.080	0.17f	22.88s	16,311	0.000	1.301	0.2278	8.963(16)
4.693	0.26f	25.38s	16,313	0.003a	1.465	0.2882	8.288(16)
4.284	0.34f	27.88s	16,312	0.002a	1.616	0.3554	7.614(16)
3.986	0.39f	29.64s	16,314	0.000	1.717	0.4066	Dk/MargImm.
3.857	0.41f	30.38s	16,314	0.000	1.758	0.4291	6.939(16)

Tablica 40. Stanje krcanja 2 – kriteriji stabiliteta u neoštećenom stanju

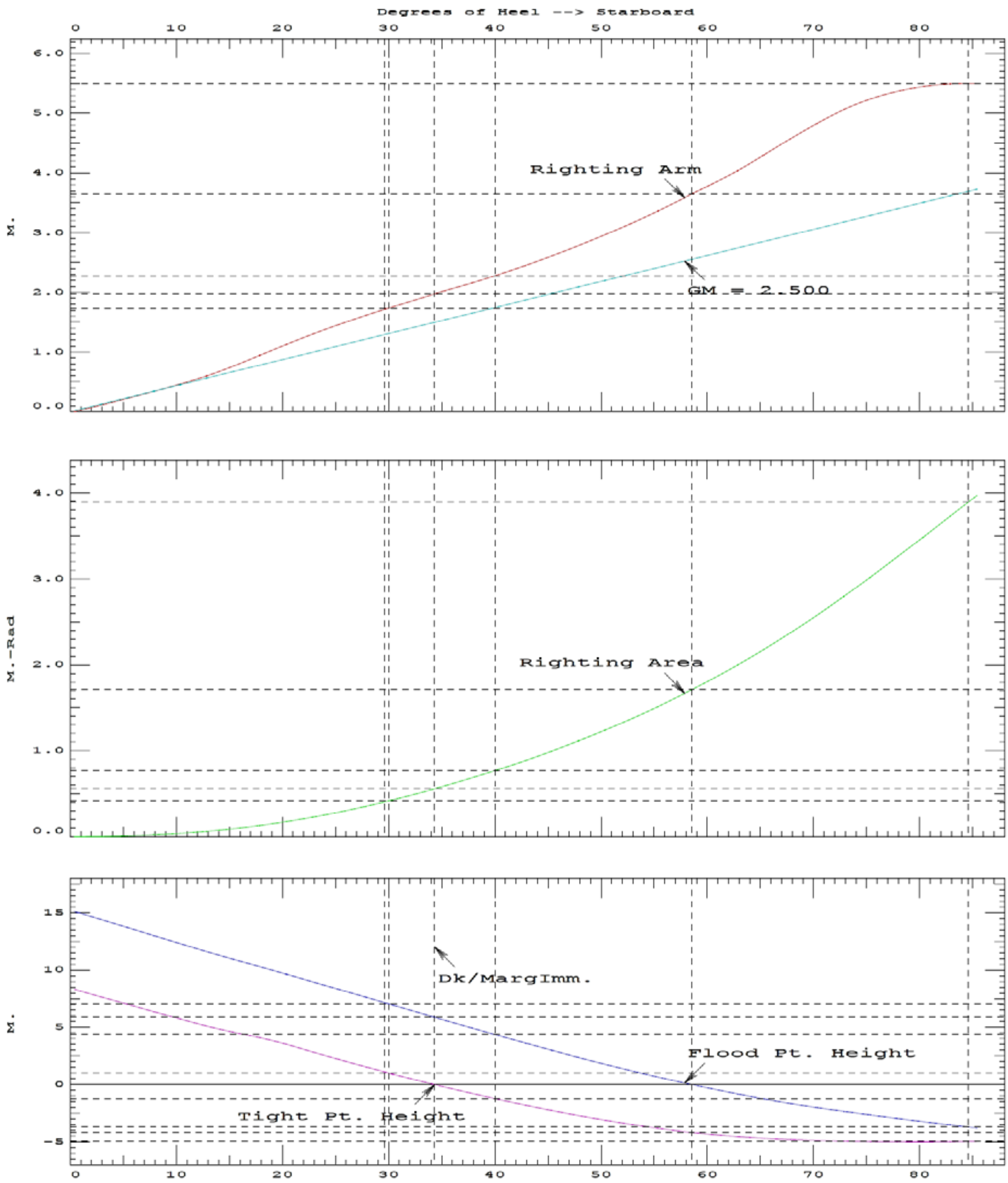
```
LOAD CONDITION 02: BALAST LOADED, T = 6,346 m, 10% STORES
```

3.411	0.48f	32.88s	16,313	0.000	1.893	0.5087	6.267(16)
3.147	0.51f	34.33s	16,314	0.000	1.973	0.5578	-0.002(7)
2.952	0.53f	35.38s	16,314	0.000	2.029	0.5943	5.596(16)
2.468	0.59f	37.88s	16,313	0.000	2.159	0.6857	4.932(16)
1.969	0.64f	40.38s	16,313	0.000	2.300	0.7830	4.275(16)
1.453	0.68f	42.88s	16,313	0.000	2.451	0.8866	3.626(16)
0.917	0.71f	45.38s	16,313	0.000	2.612	0.9970	2.990(16)
0.359	0.74f	47.88s	16,314	0.000	2.783	1.1147	2.369(16)
-0.225	0.77f	50.38s	16,313	0.000	2.966	1.2401	1.769(16)
-0.843	0.80f	52.88s	16,313	0.000	3.158	1.3737	1.196(16)
-1.491	0.84f	55.38s	16,313	0.000	3.364	1.5159	0.652(16)
-2.167	0.87f	57.88s	16,313	0.000	3.585	1.6675	0.138(16)
-2.359	0.88f	58.58s	16,314	0.000	3.650	1.7118	-0.002(16)
-2.849	0.88f	60.38s	16,314	0.000	3.809	1.8288	-0.354(16)
-3.538	0.87f	62.88s	16,314	0.000	4.040	2.0001	-0.824(16)
-4.249	0.86f	65.38s	16,314	0.000	4.305	2.1821	-1.259(16)
-4.994	0.84f	67.88s	16,314	0.000	4.577	2.3759	-1.653(16)
-5.778	0.85f	70.38s	16,313	0.003f	4.835	2.5813	-2.006(16)
-6.582	0.86f	72.88s	16,314	0.000	5.061	2.7973	-2.330(16)
-7.382	0.87f	75.38s	16,314	0.000	5.240	3.0220	-2.641(16)
-8.169	0.87f	77.88s	16,314	0.000	5.368	3.2534	-2.944(16)
-8.943	0.88f	80.38s	16,314	0.003f	5.451	3.4896	-3.237(16)
-9.700	0.87f	82.88s	16,315	0.003a	5.494	3.7285	-3.521(16)
-10.212	0.86f	84.59s	16,314	0.003f	5.501	3.8929	-3.708(16)
-10.443	0.86f	85.38s	16,314	0.000	5.500	3.9685	-3.793(16)

```
 Distances in METERS.----Specific Gravity = 1.025.-----------Area in m.-Rad.

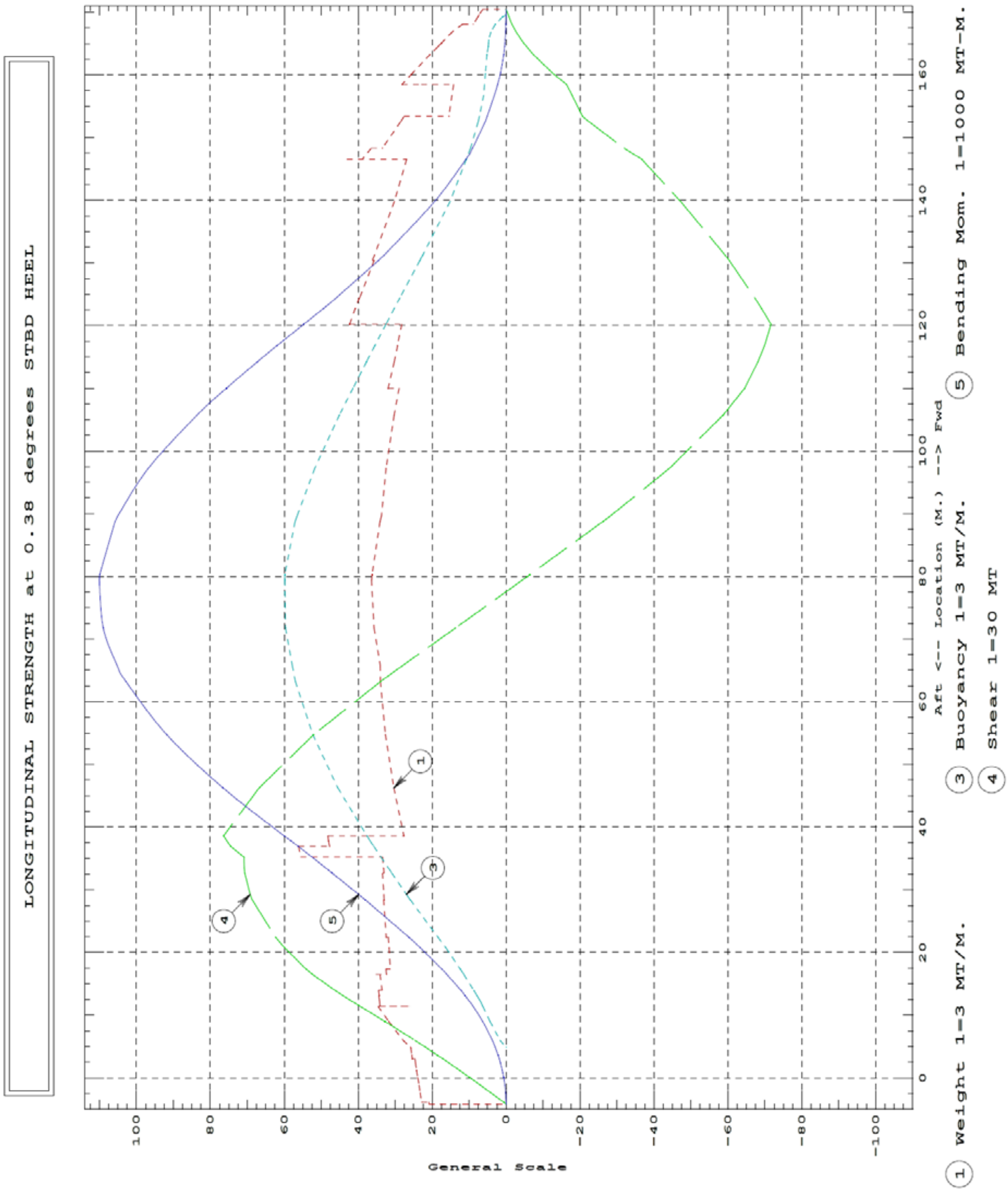
           Critical Points----------------------LCP-----TCP-----VCP
       (1) AirPipe AP SB             TIGHT   9.900a 15.100s 15.260
       (7) AirPipe DB 2 SB           TIGHT 114.680f 14.950s 15.260
      (14) ER Vent 1 SP              FLOOD  18.200f 15.550s 21.910
      (16) ER Vent 2 SB              FLOOD  33.500f 15.550s 21.910
LIM---------------IMO A.167 STABILITY CRITERION-------Min/Max--------Attained
(1)  GM Upright                                  >    0.150   m.    2.500 P
(2) Area from abs 0.379 deg to 30                >   0.0550 m.-Rad 0.4291 P
(3) Area from abs 0.379 deg to 40 or Flood       >   0.0900 m.-Rad 0.7830 P
(4) Area from 30 deg to 40 or Flood              >   0.0300 m.-Rad 0.3539 P
(5) Righting Arm at 30 deg                       >    0.200   m.    1.758 P
(6) Absolute Angle at MaxRA                      >    25.00  deg    84.59 P
--------------------Relative angles measured from 0.379s--------------------
```

LOAD CONDITION 02: BALAST LOADED, T = 6,346 m, 10% STORES



Slika 33. Stanje krcanja 2 – karakteristike stabiliteta

LOAD CONDITION 02: BALAST LOADED, T = 6,346 m, 10% STORES

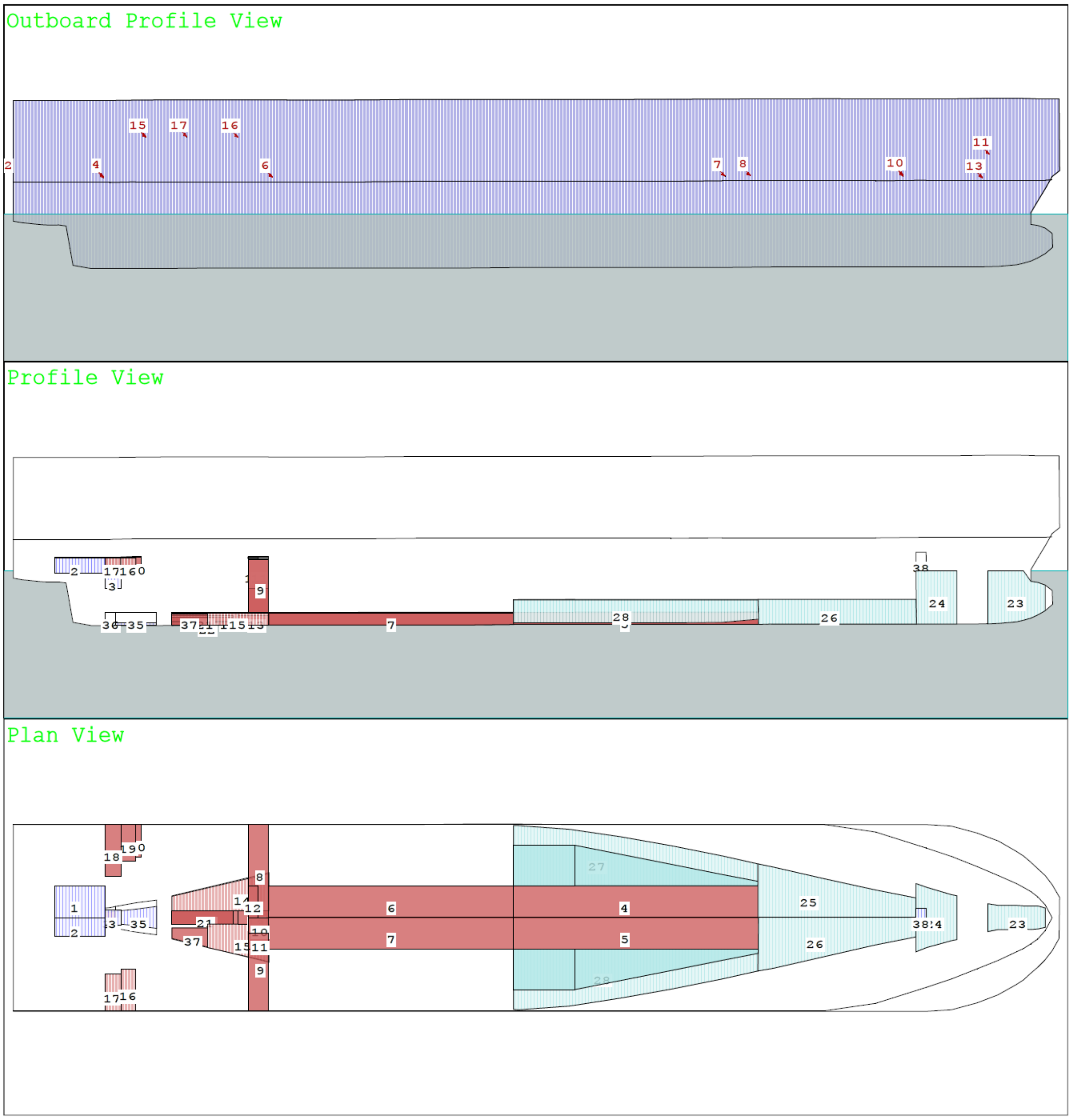


Slika 34. Stanje krcanja 2 – karakteristike uzdužne čvrstoće

iii. Stanje krcanja 3 – homogeno sa 100% zaliha

LOAD CONDITION 03: HOMOGENOUS LOADED, T=8.750 m, 100% STORES

CG - Draft: 9.113 @ 0.000 Trim: aft 0.32/165.00 Heel: stbd 0.23 deg.



Slika 35. Stanje krcanja 3 – prikaz tankova i kritičnih točaka

Tablica 41. Stanje krcanja 3 – homogeno sa 10% zaliha, neoštećeno

LOAD CONDITION 03: HOMOGENOUS LOADED, T=8.750 m, 100% STORES

WEIGHT and DISPLACEMENT and CRITICAL POINT STATUS
Baseline draft: 9.113 @ Origin
Trim: Aft 0.32/165.00, Heel: Stbd 0.23 deg.

Part	Weight (MT)	LCG	TCG	VCG
LIGHT SHIP	13,075.55	76.196f	0.039s	14.902
hold_1.c	1,516.98	140.325f	0.000	19.760
hold_2.c	2,336.74	99.800f	0.000	15.690
hold_3.c	2,309.20	59.000f	0.000	15.680
hold_4.c	1,363.76	16.983f	0.000	20.760
CREW & EFFECTS	2.50	128.275f	0.000	29.300
PROVIANT	12.00	120.625f	0.000	29.200
Total Fixed--------->	20,616.73	77.779f	0.025s	15.834

Part	Load	SpGr	Weight (MT)	LCG	TCG	VCG	FSM
FW_TANK.P	0.950	1.000	103.48	7.195f	2.621p	10.045	96.2
FW_TANK.S	0.950	1.000	61.60	7.195f	1.564s	10.045	20.3
FW_FEED_TANK.C	0.950	1.000	15.19	12.675f	0.001	7.424	3.2
HFO_DBTANK_2.P	0.950	0.960	359.15	99.552f	2.536p	1.061	448.7
HFO_DBTANK_2.S	0.950	0.960	359.15	99.552f	2.546s	1.061	448.7
HFO_DBTANK_3.P	0.950	0.960	360.60	58.884f	2.544p	1.058	448.7
HFO_DBTANK_3.S	0.950	0.960	360.60	58.884f	2.554s	1.058	448.7
HFO_TANK.P	0.950	0.960	277.37	37.041f	6.495p	6.962	693.1
HFO_TANK.S	0.950	0.960	236.85	36.922f	7.145s	6.672	282.4
HFO_SETT_1.S	0.950	0.960	40.52	36.900f	1.313s	8.659	4.7
HFO_SETT_2.S	0.950	0.960	40.52	36.900f	3.938s	8.659	4.7
HFO_DAILYTNK.P	0.950	0.960	40.52	36.050f	2.623p	8.659	18.7
HFO_OVERFLOW.C	0.770	0.960	16.59	36.046f	0.001s	0.814	4.4
DO_STORAGE.P	0.950	0.860	81.58	31.693f	2.930p	1.177	117.1
DO_STORAGE.S	0.950	0.860	60.00	33.902f	3.148s	1.174	95.8
DO_DAILY_1.S	0.950	0.860	28.31	15.235f	11.545s	10.283	60.3
DO_DAILY_2.S	0.950	0.860	22.81	12.683f	12.075s	10.394	41.4
LO_MECYL_OIL.P	0.950	0.900	38.59	12.685f	10.495p	10.221	121.7
LO_MEOILSTOR.P	0.950	0.900	24.61	15.234f	12.065p	10.348	42.3
LO_AUXOILSTR.P	0.950	0.900	7.32	16.926f	12.412p	10.362	10.4
LO_MEOILCIRC.C	0.750	0.900	12.29	27.523f	0.003s	1.013	8.3
LO_REN_TANK.C	0.700	0.900	10.16	27.906f	0.003s	0.256	9.0
SW_FOREPEAK.C	1.000	1.025	179.29	162.555f	0.000	4.698	0.0
SW_DEEPTANK.C	1.000	1.025	310.36	149.709f	0.000	5.429	0.0
SW_DB_TANK_1.P	1.000	1.025	439.28	130.905f	2.554p	2.437	0.0
SW_DB_TANK_1.S	1.000	1.025	439.28	130.905f	2.554s	2.437	0.0
SW_DB_TANK_2.P	1.000	1.025	474.28	96.332f	9.180p	2.075	0.0
SW_DB_TANK_2.S	1.000	1.025	474.28	96.332f	9.180s	2.075	0.0
BILGE_TANK.C	0.100	1.000	4.90	16.911f	0.011s	0.238	13.3
STERN_OIL_DR.C	0.100	0.924	0.81	12.256f	0.004s	0.243	0.9
OIL_DR_TANK.S	0.850	0.924	15.66	25.734f	2.676s	1.163	7.2
SEWAGE_TANK.C	0.050	1.000	0.76	147.397f	0.019s	8.889	3.6
Total Tanks--------->			4,896.67	87.605f	0.075p	3.261	3453.6
Total Weight-------->			25,513.39	79.665f	0.006s	13.421	

Tablica 42. Stanje krcanja 3 – kritične točke, hidrostatičke karakteristike i poluga stabiliteta

```
 LOAD CONDITION 03: HOMOGENOUS LOADED, T=8.750 m, 100% STORES


                              STATUS, continued
Part---------------------SpGr------Displ(MT)----LCB-----TCB-----VCB
HULL                     1.025     25,512.69  79.652f  0.038s  5.093
------------------------------------------------------------------------------
               Righting Arms:                 0.003f  0.000s
Distances in METERS.-----------------------------------------Moments in m.-MT.

       Critical Points----------------------LCP-----TCP-----VCP-----Height
    (1) AirPipe AP SB            TIGHT   9.900a 15.100s 15.260      6.069
    (2) AirPipe AP PS            TIGHT   9.900a 15.100p 15.260      6.188
    (3) AirPipe FreshW SB        TIGHT  11.110f 15.100s 15.260      6.109
    (4) AirPipe FreshW PS        TIGHT  11.110f 15.100p 15.260      6.228
    (5) AirPipe DB 3 SB          TIGHT  39.250f 15.130s 15.260      6.164
    (6) AirPipe DB 3 PS          TIGHT  39.250f 15.130s 15.260      6.164
    (7) AirPipe DB 2 SB          TIGHT 114.680f 14.950s 15.260      6.310
    (8) AirPipe DB 2 PS          TIGHT 118.920f 14.950p 15.260      6.436
    (9) AirPipe DB 1 SB          TIGHT 144.400f 12.060s 15.260      6.378
   (10) AirPipe DB 1 PS          TIGHT 144.400f 12.060p 15.260      6.473
   (11) AirPipe FP               TIGHT 158.750f 10.150p 18.710      9.944
   (12) Weath Door Domest        TIGHT 157.650f  0.600p 14.910      6.104
   (13) Weath Door Bosuns        TIGHT 157.650f  1.400s 14.910      6.096
   (14) ER Vent 1 SP             FLOOD  18.200f 15.550s 21.910     12.771
   (15) ER Vent 1 PS             FLOOD  18.200f 15.550p 21.910     12.894
   (16) ER Vent 2 SB             FLOOD  33.500f 15.550s 21.910     12.801
   (17) ER Vent 2 PS             FLOOD  25.000f 15.550p 21.910     12.907
    Distances in METERS.--------------------------------------------------

                           HYDROSTATIC PROPERTIES
                  Trim: Aft 0.32/165.00, Heel: Stbd 0.23 deg.

 Origin  Displacement     Center of Buoyancy
  Depth----Weight(MT)----LCB-----TCB-----VCB-----WPA-----LCF------BML-----BMT
  9.112     25,512.69  79.652f  0.038s  5.093  3977.5  72.882f  262.22   9.572
Distances in METERS.----Specific Gravity = 1.025.---True Free Surface included.


                          RIGHTING ARMS vs HEEL ANGLE
       Total CG:  LCG = 79.665f  TCG = 0.006s  VCG = 13.421
                             Free Surface Adjustment:   0.135
    Adjusted CG:  LCG = 79.665f  TCG = 0.005s  VCG = 13.556

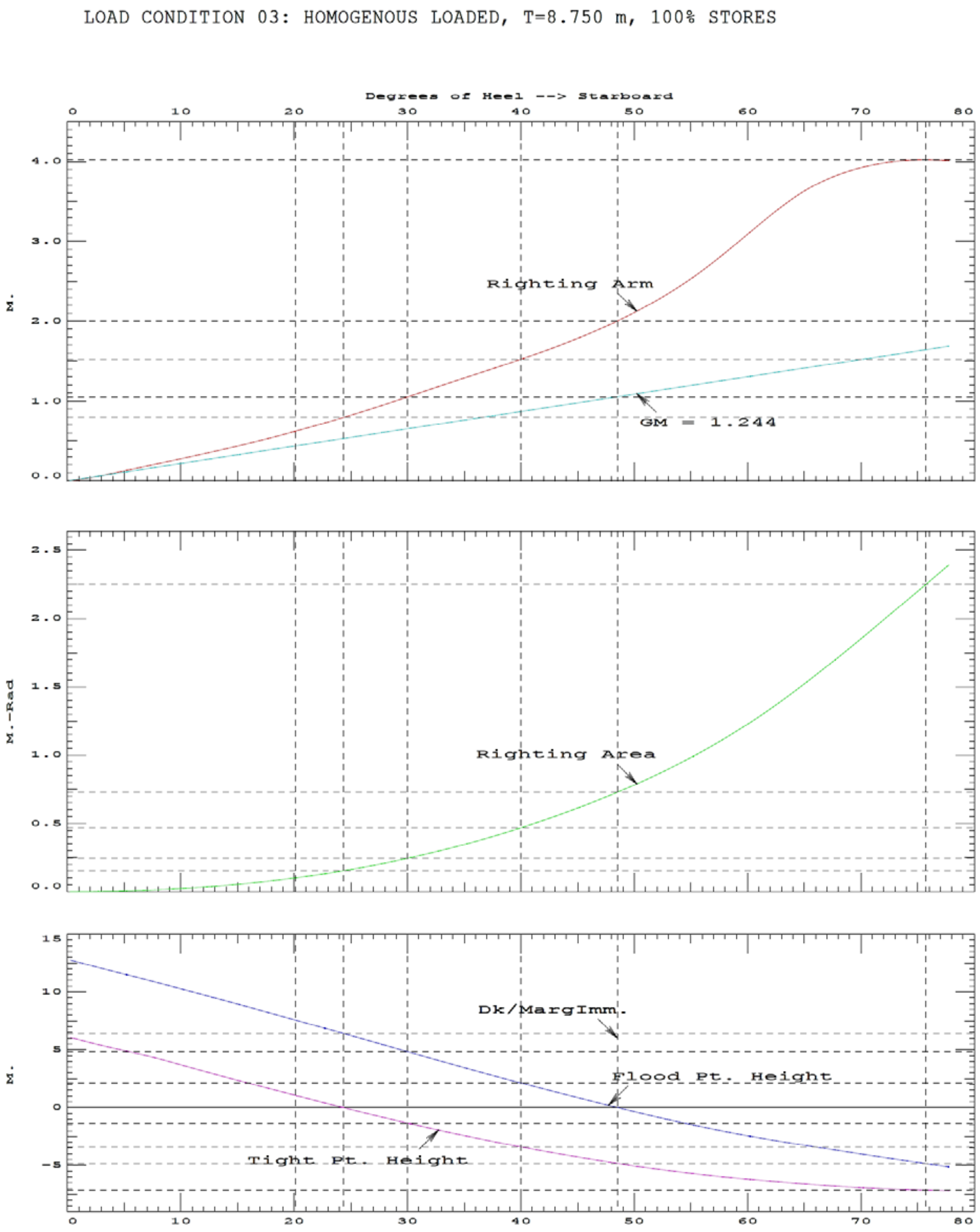
  Origin    Degrees of   Displacement    Righting Arms          Flood Pt
   Depth---Trim----Heel----Weight(MT)---in Trim--in Heel---> Area--Height
   9.114   0.11a   0.23s      25,515    0.000    0.000    0.0000   6.067(1)
   9.065   0.09a   2.73s      25,513    0.000    0.058    0.0013  12.110(14)
   8.931   0.04a   5.23s      25,513    0.000    0.132    0.0054  11.484(14)
   8.747   0.03f   7.73s      25,513    0.000    0.208    0.0128  10.858(16)
   8.531   0.10f  10.23s      25,513    0.000    0.283    0.0235  10.214(16)
   8.290   0.17f  12.73s      25,512    0.000    0.361    0.0375   9.560(16)
   8.026   0.23f  15.23s      25,512    0.000    0.442    0.0550   8.896(16)
   7.742   0.29f  17.73s      25,512    0.002a   0.530    0.0762   8.223(16)
```

Tablica 43. Stanje krcanja 3 – kriteriji stabiliteta u neoštećenom stanju

```
LOAD CONDITION 03: HOMOGENOUS LOADED, T=8.750 m, 100% STORES

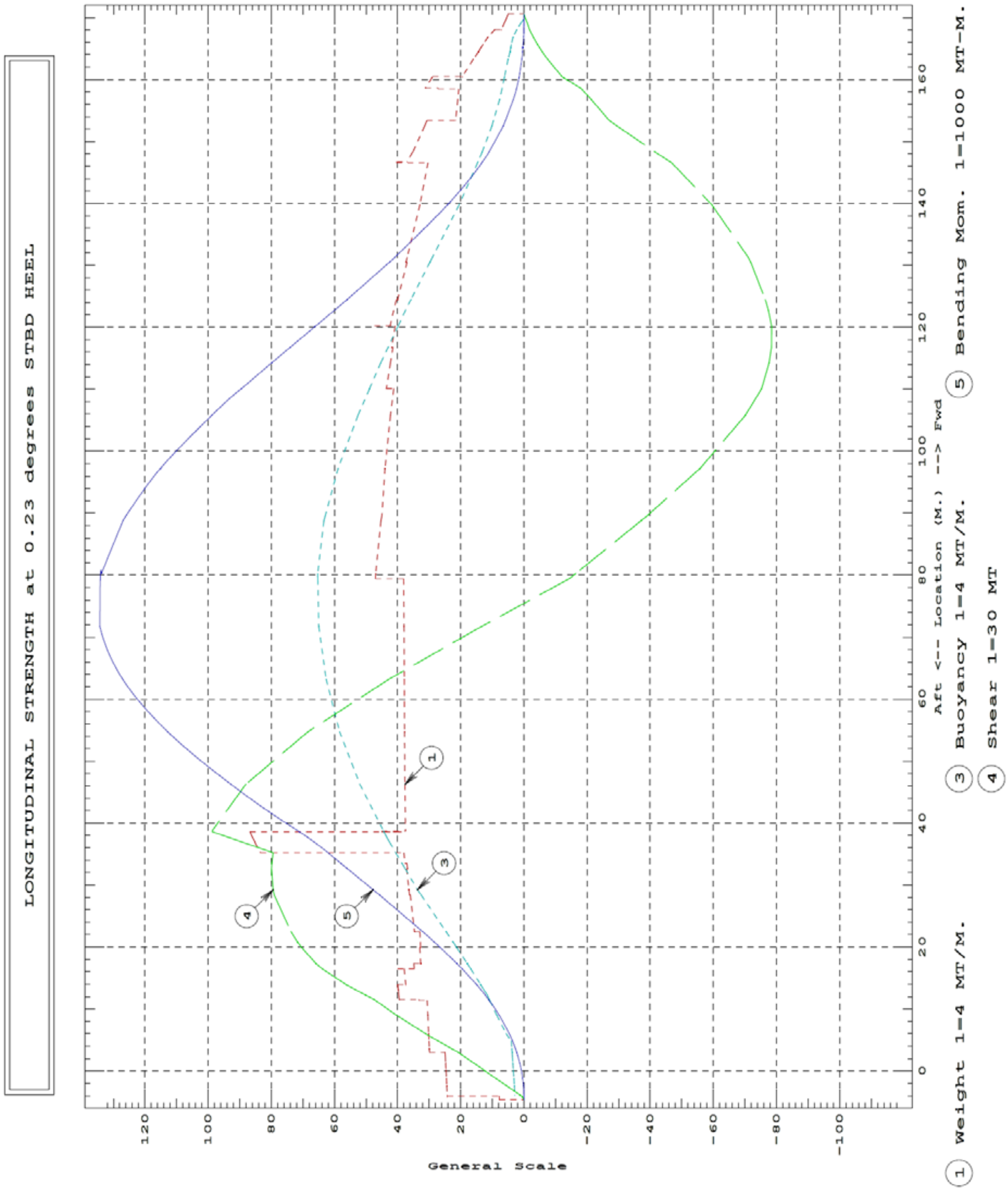

   7.458   0.34f  20.08s      25,513    0.002a   0.618    0.0998 Dk/MargImm.
   7.438   0.35f  20.23s      25,513    0.002f   0.624    0.1013   7.542(16)
   7.117   0.39f  22.73s      25,513    0.000    0.725    0.1308   6.854(16)
   6.901   0.42f  24.33s      25,513    0.000    0.794    0.1520  -0.002(7)
   6.776   0.44f  25.23s      25,513    0.000    0.832    0.1647   6.161(16)
   6.414   0.48f  27.73s      25,513    0.000    0.943    0.2034   5.467(16)
   6.034   0.51f  30.23s      25,513    0.000    1.061    0.2471   4.774(16)
   5.631   0.53f  32.73s      25,513    0.000    1.180    0.2960   4.084(16)
   5.204   0.55f  35.23s      25,513    0.000    1.297    0.3500   3.403(16)
   4.751   0.57f  37.73s      25,513    0.000    1.413    0.4092   2.731(16)
   4.276   0.58f  40.23s      25,513    0.000    1.534    0.4735   2.071(16)
   3.772   0.59f  42.73s      25,513    0.000    1.659    0.5431   1.426(16)
   3.243   0.60f  45.23s      25,513    0.000    1.796    0.6185   0.797(16)
   2.689   0.61f  47.73s      25,513    0.000    1.950    0.7002   0.186(16)
   2.507   0.61f  48.52s      25,513    0.000    2.002    0.7274  -0.002(16)
   2.106   0.62f  50.23s      25,513    0.000    2.123    0.7890  -0.403(16)
   1.495   0.63f  52.73s      25,513    0.000    2.322    0.8859  -0.968(16)
   0.854   0.64f  55.23s      25,513    0.000    2.554    0.9921  -1.505(16)
   0.181   0.65f  57.73s      25,513    0.000    2.822    1.1093  -2.010(16)
  -0.536   0.67f  60.23s      25,513    0.000    3.118    1.2389  -2.473(16)
  -1.302   0.71f  62.73s      25,513    0.000    3.404    1.3811  -2.895(16)
  -2.093   0.76f  65.23s      25,512    0.000    3.650    1.5352  -3.291(16)
  -2.881   0.81f  67.73s      25,513    0.000    3.820    1.6984  -3.674(16)
  -3.656   0.83f  70.23s      25,513    0.000    3.931    1.8677  -4.051(16)
  -4.419   0.85f  72.73s      25,513    0.000    3.997    2.0407  -4.421(16)
  -5.175   0.86f  75.23s      25,514    0.003f   4.023    2.2156  -4.778(16)
  -5.326   0.87f  75.73s      25,513    0.002a   4.023    2.2511  -4.849(16)
  -5.924   0.87f  77.73s      25,513    0.000    4.012    2.3910  -5.122(16)
  Distances in METERS.----Specific Gravity = 1.025.-----------Area in m.-Rad.

            Critical Points----------------------LCP-----TCP-----VCP
        (1) AirPipe AP SB             TIGHT   9.900a 15.100s 15.260
        (7) AirPipe DB 2 SB           TIGHT 114.680f 14.950s 15.260
       (14) ER Vent 1 SP              FLOOD  18.200f 15.550s 21.910
       (16) ER Vent 2 SB              FLOOD  33.500f 15.550s 21.910
LIM---------------IMO A.167 STABILITY CRITERION-------Min/Max--------Attained
(1)  GM Upright                                >    0.150   m.     1.244 P
(2) Area from abs 0.226 deg to 30              >   0.0550 m.-Rad 0.2471 P
(3) Area from abs 0.226 deg to 40 or Flood     >   0.0900 m.-Rad 0.4735 P
(4) Area from 30 deg to 40 or Flood            >   0.0300 m.-Rad 0.2263 P
(5) Righting Arm at 30 deg                     >    0.200   m.     1.061 P
(6) Absolute Angle at MaxRA                    >    25.00  deg     75.73 P
--------------------Relative angles measured from 0.226s---------------------
```



Slika 36. Stanje krcanja 3 – karakteristike stabiliteta

LOAD CONDITION 03: HOMOGENOUS LOADED, T=8.750 m, 100% STORES

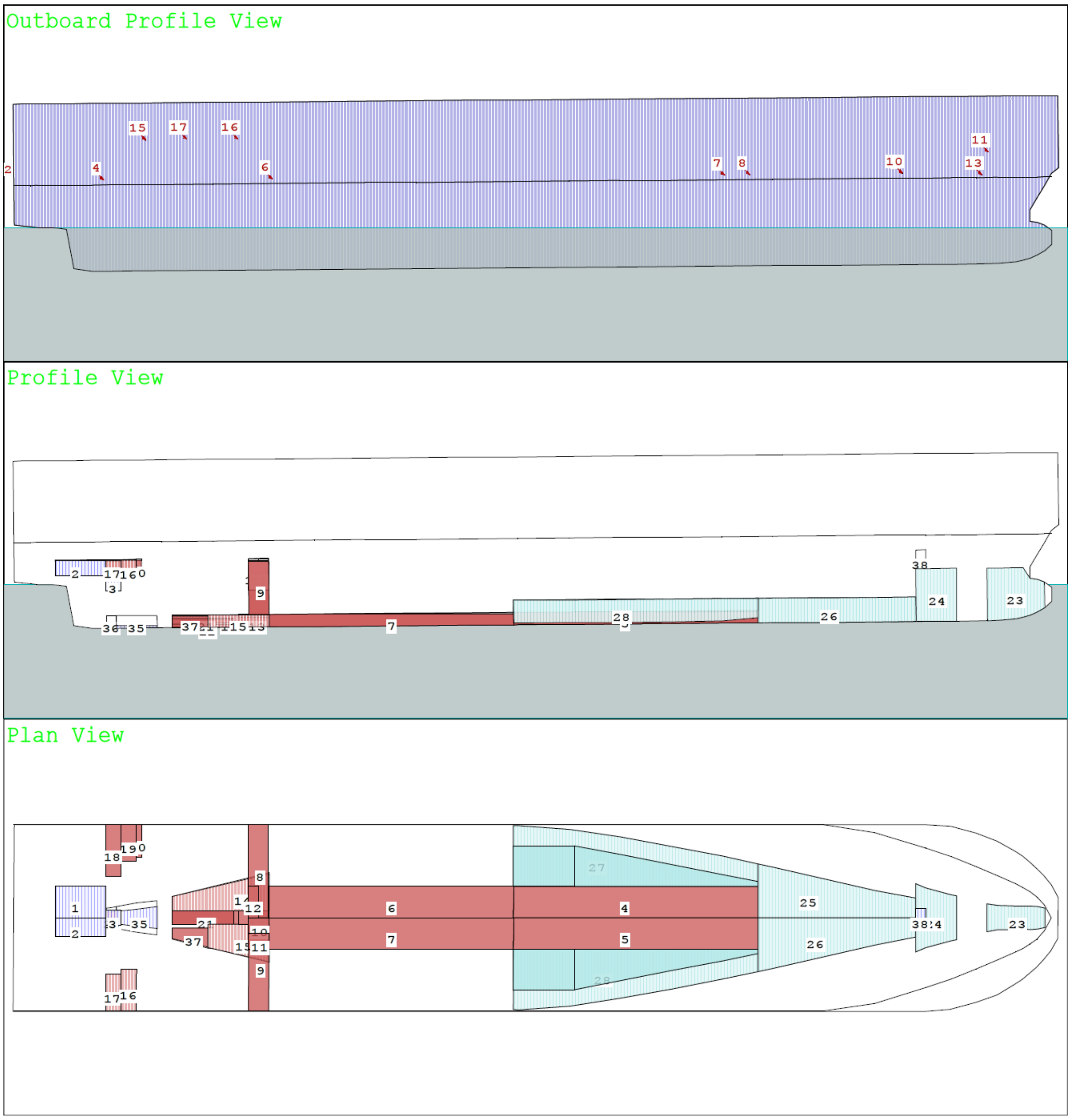


Slika 37. Stanje krcanja 3 – karakteristike uzdužne čvrstoće

iv. Stanje krcanja 4 – balastno sa 100% zaliha

LOAD CONDITION 04: BALAST LOADED, T = 6,647 m, 100% STORES

CG - Draft: 7.367 @ 0.000 Trim: aft 1.36/165.00 Heel: stbd 0.14 deg.



Slika 38. Stanje krcanja 4 – prikaz tankova i kritičnih točaka

Tablica 44. Stanje krcanja 4 – homogeno sa 10% zaliha, neoštećeno

```
LOAD CONDITION 04: BALAST LOADED, T = 6,647 m, 100% STORES

             WEIGHT and DISPLACEMENT and CRITICAL POINT STATUS
                      Baseline draft: 7.367 @ Origin
                Trim: Aft 1.36/165.00,  Heel: Stbd 0.14 deg.
Part---------------------------------Weight(MT)----LCG-----TCG-----VCG
LIGHT SHIP                          12,427.87  76.088f  0.040s 14.838
CREW & EFFECTS                           2.50 128.275f  0.000  29.300
PROVIANT                                12.00 120.625f  0.000  29.200
  Total Fixed--------->             12,442.37  76.141f  0.040s 14.855
                Load-----SpGr-----Weight(MT)----LCG-----TCG-----VCG-------FSM
FW_TANK.P       0.950    1.000        103.48    7.180f  2.623p 10.045      96.2
FW_TANK.S       0.950    1.000         61.60    7.180f  1.563s 10.045      20.3
FW_FEED_TANK.C  0.950    1.000         15.19   12.673f  0.000   7.424       3.2
HFO_DBTANK_2.P  0.950    0.960        359.10   99.169f  2.539p  1.062     305.1
HFO_DBTANK_2.S  0.950    0.960        359.10   99.169f  2.543s  1.062     305.1
HFO_DBTANK_3.P  0.950    0.960        360.57   58.502f  2.547p  1.059     314.8
HFO_DBTANK_3.S  0.950    0.960        360.57   58.502f  2.551s  1.059     314.8
HFO_TANK.P      0.950    0.960        277.37   37.040f  6.500p  6.962     693.2
HFO_TANK.S      0.950    0.960        236.85   36.922f  7.143s  6.672     282.4
HFO_SETT_1.S    0.950    0.960         40.52   36.898f  1.313s  8.659       4.7
HFO_SETT_2.S    0.950    0.960         40.52   36.898f  3.938s  8.659       4.7
HFO_DAILYTNK.P  0.950    0.960         40.52   36.050f  2.624p  8.659      18.7
HFO_OVERFLOW.C  0.770    0.960         16.59   36.037f  0.001   0.814       4.4
DO_STORAGE.P    0.950    0.860         81.60   31.608f  2.923p  1.179      97.7
DO_STORAGE.S    0.950    0.860         60.00   33.864f  3.141s  1.176      95.0
DO_DAILY_1.S    0.950    0.860         28.31   15.233f 11.542s 10.283      60.3
DO_DAILY_2.S    0.950    0.860         22.81   12.681f 12.072s 10.394      41.4
LO_MECYL_OIL.P  0.950    0.900         38.59   12.683f 10.499p 10.221     121.7
LO_MEOILSTOR.P  0.950    0.900         24.61   15.232f 12.068p 10.348      42.3
LO_AUXOILSTR.P  0.950    0.900          7.32   16.926f 12.414p 10.362      10.4
LO_MEOILCIRC.C  0.750    0.900         12.29   27.436f  0.002s  1.014       8.3
LO_REN_TANK.C   0.700    0.900         10.16   27.771f  0.002s  0.257       9.0
SW_FOREPEAK.C   1.000    1.025        179.29  162.555f  0.000   4.698       0.0
SW_DEEPTANK.C   1.000    1.025        310.36  149.709f  0.000   5.429       0.0
SW_DB_TANK_1.P  1.000    1.025        439.28  130.905f  2.554p  2.437       0.0
SW_DB_TANK_1.S  1.000    1.025        439.28  130.905f  2.554s  2.437       0.0
SW_DB_TANK_2.P  1.000    1.025        474.28   96.332f  9.180p  2.075       0.0
SW_DB_TANK_2.S  1.000    1.025        474.28   96.332f  9.180s  2.075       0.0
BILGE_TANK.C    0.100    1.000          4.90   16.823f  0.006s  0.239      13.2
STERN_OIL_DR.C  0.100    0.924          0.81   12.251f  0.003s  0.243       0.9
OIL_DR_TANK.S   0.850    0.924         15.66   25.719f  2.673s  1.165       7.2
SEWAGE_TANK.C   0.050    1.000          0.76  147.387f  0.011s  8.889       3.6
  Total Tanks--------->              4,896.52  87.489f  0.077p  3.262    2878.4
  Total Weight-------->             17,338.89  79.346f  0.007s 11.581
                                     Displ(MT)----LCB-----TCB-----VCB
HULL                     1.025      17,338.98  79.282f  0.026s  3.783
------------------------------------------------------------------------------
               Righting Arms:                   0.000   0.000
Distances in METERS.-----------------------------------------Moments in m.-MT.
```

Tablica 45. Stanje krcanja 4 – kritične točke, hidrostatičke karakteristike i poluga stabiliteta

LOAD CONDITION 04: BALAST LOADED, T = 6,647 m, 100% STORES

	Critical Points		LCP	TCP	VCP	Height
(1)	AirPipe AP SB	TIGHT	9.900a	15.100s	15.260	7.775
(2)	AirPipe AP PS	TIGHT	9.900a	15.100p	15.260	7.846
(3)	AirPipe FreshW SB	TIGHT	11.110f	15.100s	15.260	7.948
(4)	AirPipe FreshW PS	TIGHT	11.110f	15.100p	15.260	8.020
(5)	AirPipe DB 3 SB	TIGHT	39.250f	15.130s	15.260	8.180
(6)	AirPipe DB 3 PS	TIGHT	39.250f	15.130s	15.260	8.180
(7)	AirPipe DB 2 SB	TIGHT	114.680f	14.950s	15.260	8.804
(8)	AirPipe DB 2 PS	TIGHT	118.920f	14.950p	15.260	8.910
(9)	AirPipe DB 1 SB	TIGHT	144.400f	12.060s	15.260	9.056
(10)	AirPipe DB 1 PS	TIGHT	144.400f	12.060p	15.260	9.113
(11)	AirPipe FP	TIGHT	158.750f	10.150p	18.710	12.677
(12)	Weath Door Domest	TIGHT	157.650f	0.600p	14.910	8.846
(13)	Weath Door Bosuns	TIGHT	157.650f	1.400s	14.910	8.841
(14)	ER Vent 1 SP	FLOOD	18.200f	15.550s	21.910	14.655
(15)	ER Vent 1 PS	FLOOD	18.200f	15.550p	21.910	14.729
(16)	ER Vent 2 SB	FLOOD	33.500f	15.550s	21.910	14.782
(17)	ER Vent 2 PS	FLOOD	25.000f	15.550p	21.910	14.785

Distances in METERS.

HYDROSTATIC PROPERTIES

Trim: Aft 1.36/165.00, Heel: Stbd 0.14 deg.

Origin Depth	Displacement Weight(MT)	LCB	TCB	VCB	WPA	LCF	BML	BMT
7.367	17,338.98	79.282f	0.026s	3.783	3256.6	79.942f	239.99	10.561

Distances in METERS.----Specific Gravity = 1.025.---True Free Surface included.

RIGHTING ARMS vs HEEL ANGLE

Total CG: LCG = 79.346f TCG = 0.007s VCG = 11.581

Free Surface Adjustment: 0.166

Adjusted CG: LCG = 79.347f TCG = 0.007s VCG = 11.747

Origin Depth	Trim (deg)	Heel (deg)	Displacement Weight(MT)	Righting Arms in Trim	Righting Arms in Heel	Area	Flood Pt Height
7.367	0.47a	0.14s	17,339	0.000	0.000	0.0000	7.775(1)
7.349	0.47a	2.64s	17,339	0.000	0.122	0.0027	13.971(14)
7.296	0.46a	5.14s	17,339	0.000	0.247	0.0107	13.279(14)
7.205	0.44a	7.64s	17,339	0.000	0.378	0.0243	12.582(14)
7.070	0.40a	10.14s	17,339	0.002a	0.518	0.0438	11.889(14)
6.850	0.33a	12.64s	17,339	0.000	0.688	0.0701	11.233(14)
6.550	0.23a	15.14s	17,339	0.003f	0.881	0.1044	10.612(14)
6.226	0.12a	17.64s	17,348	0.000	1.074	0.1470	9.983(14)
5.877	0.03a	20.14s	17,338	0.002a	1.264	0.1980	9.349(14)
5.514	0.07f	22.64s	17,348	0.002a	1.450	0.2573	8.683(16)
5.127	0.16f	25.14s	17,338	0.003a	1.629	0.3244	8.011(16)
4.723	0.24f	27.64s	17,338	0.003a	1.798	0.3992	7.335(16)
4.509	0.28f	28.90s	17,339	0.000	1.879	0.4399	Dk/MargImm.
4.296	0.32f	30.14s	17,338	0.000	1.955	0.4811	6.661(16)

Tablica 46. Stanje krcanja 4 – kriteriji stabiliteta u neoštećenom stanju

```
LOAD CONDITION 04: BALAST LOADED, T = 6,647 m, 100% STORES


   3.855   0.38f  32.64s      17,338     0.002a   2.109    0.5698   5.987(16)
   3.717   0.40f  33.40s      17,339     0.000    2.156    0.5982  -0.002(7)
   3.395   0.44f  35.14s      17,339     0.002a   2.258    0.6651   5.317(16)
   2.913   0.49f  37.64s      17,338     0.000    2.403    0.7668   4.654(16)
   2.418   0.54f  40.14s      17,338     0.000    2.559    0.8750   3.996(16)
   1.905   0.57f  42.64s      17,339     0.000    2.724    0.9903   3.346(16)
   1.371   0.61f  45.14s      17,339     0.000    2.898    1.1129   2.709(16)
   0.815   0.64f  47.64s      17,339     0.000    3.081    1.2433   2.088(16)
   0.234   0.66f  50.14s      17,339     0.000    3.279    1.3820   1.486(16)
  -0.375   0.69f  52.64s      17,339     0.000    3.490    1.5297   0.907(16)
  -1.017   0.72f  55.14s      17,338     0.000    3.715    1.6868   0.359(16)
  -1.478   0.75f  56.86s      17,339     0.003a   3.880    1.8011  -0.001(16)
  -1.690   0.75f  57.64s      17,339     0.000    3.957    1.8541  -0.157(16)
  -2.386   0.78f  60.14s      17,339     0.000    4.206    2.0322  -0.643(16)
  -3.085   0.77f  62.64s      17,339     0.000    4.455    2.2211  -1.105(16)
  -3.807   0.76f  65.14s      17,339     0.000    4.735    2.4216  -1.534(16)
  -4.565   0.76f  67.64s      17,339     0.000    5.022    2.6344  -1.922(16)
  -5.356   0.77f  70.14s      17,339     0.000    5.280    2.8593  -2.272(16)
  -6.160   0.78f  72.64s      17,339     0.000    5.493    3.0944  -2.599(16)
  -6.954   0.79f  75.14s      17,339     0.000    5.654    3.3376  -2.917(16)
  -7.736   0.80f  77.64s      17,339     0.000    5.766    3.5868  -3.227(16)
  -8.504   0.80f  80.14s      17,339     0.003a   5.833    3.8400  -3.527(16)
  -9.259   0.79f  82.64s      17,339     0.003a   5.862    4.0953  -3.816(16)
  -9.456   0.79f  83.29s      17,339     0.003f   5.863    4.1625  -3.890(16)
  -9.998   0.78f  85.14s      17,339     0.000    5.854    4.3510  -4.094(16)
  Distances in METERS.----Specific Gravity = 1.025.-----------Area in m.-Rad.

            Critical Points----------------------LCP-----TCP-----VCP
        (1) AirPipe AP SB             TIGHT   9.900a 15.100s 15.260
        (7) AirPipe DB 2 SB           TIGHT 114.680f 14.950s 15.260
       (14) ER Vent 1 SP              FLOOD  18.200f 15.550s 21.910
       (16) ER Vent 2 SB              FLOOD  33.500f 15.550s 21.910
LIM---------------IMO A.167 STABILITY CRITERION-------Min/Max--------Attained
(1)  GM Upright                                >    0.150   m.    2.762 P
(2) Area from abs 0.136 deg to 30              >   0.0550 m.-Rad 0.4811 P
(3) Area from abs 0.136 deg to 40 or Flood     >   0.0900 m.-Rad 0.8750 P
(4) Area from 30 deg to 40 or Flood            >   0.0300 m.-Rad 0.3939 P
(5) Righting Arm at 30 deg                     >    0.200   m.    1.955 P
(6) Absolute Angle at MaxRA                    >    25.00  deg    83.29 P
--------------------Relative angles measured from 0.136 ---------------------
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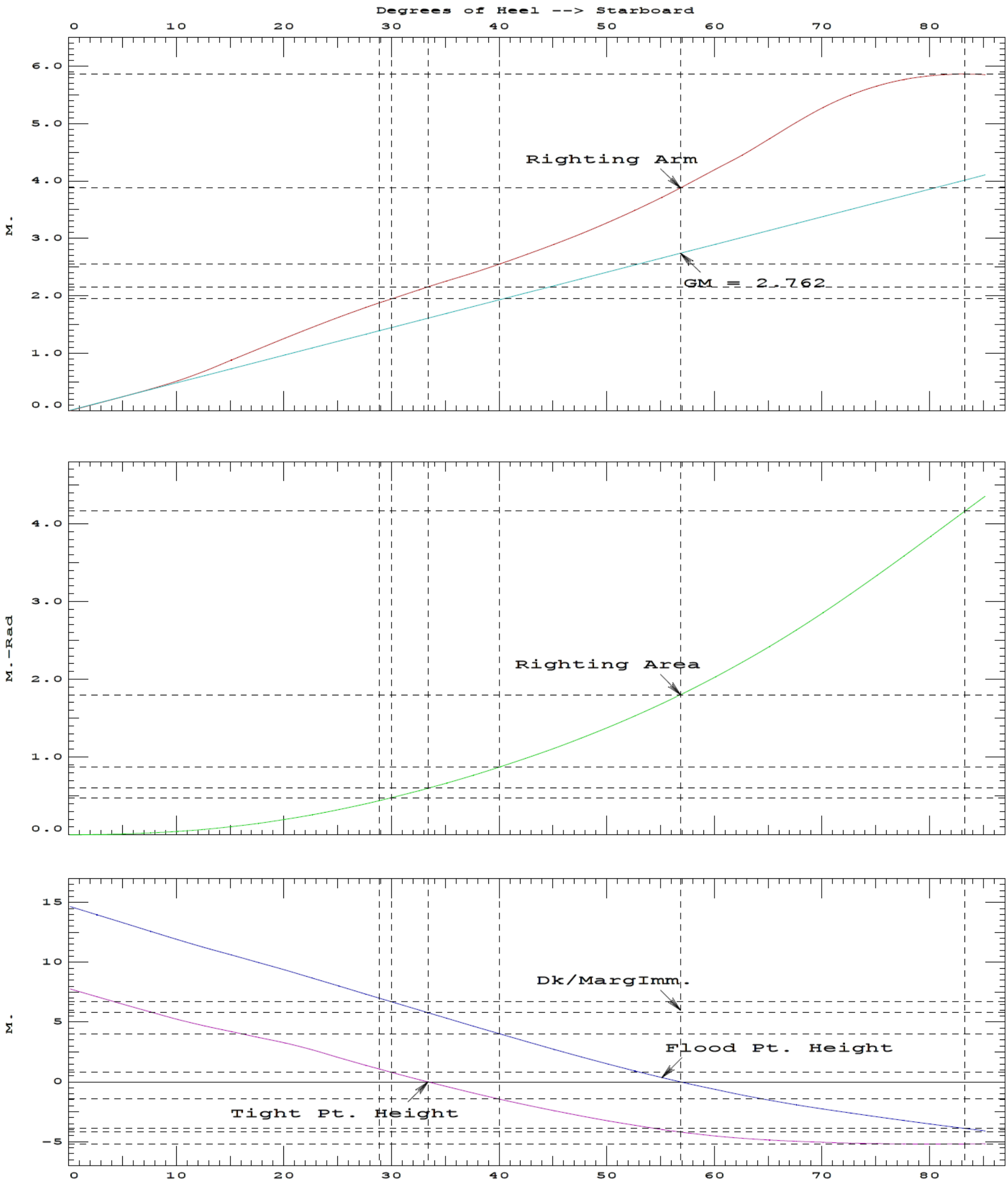
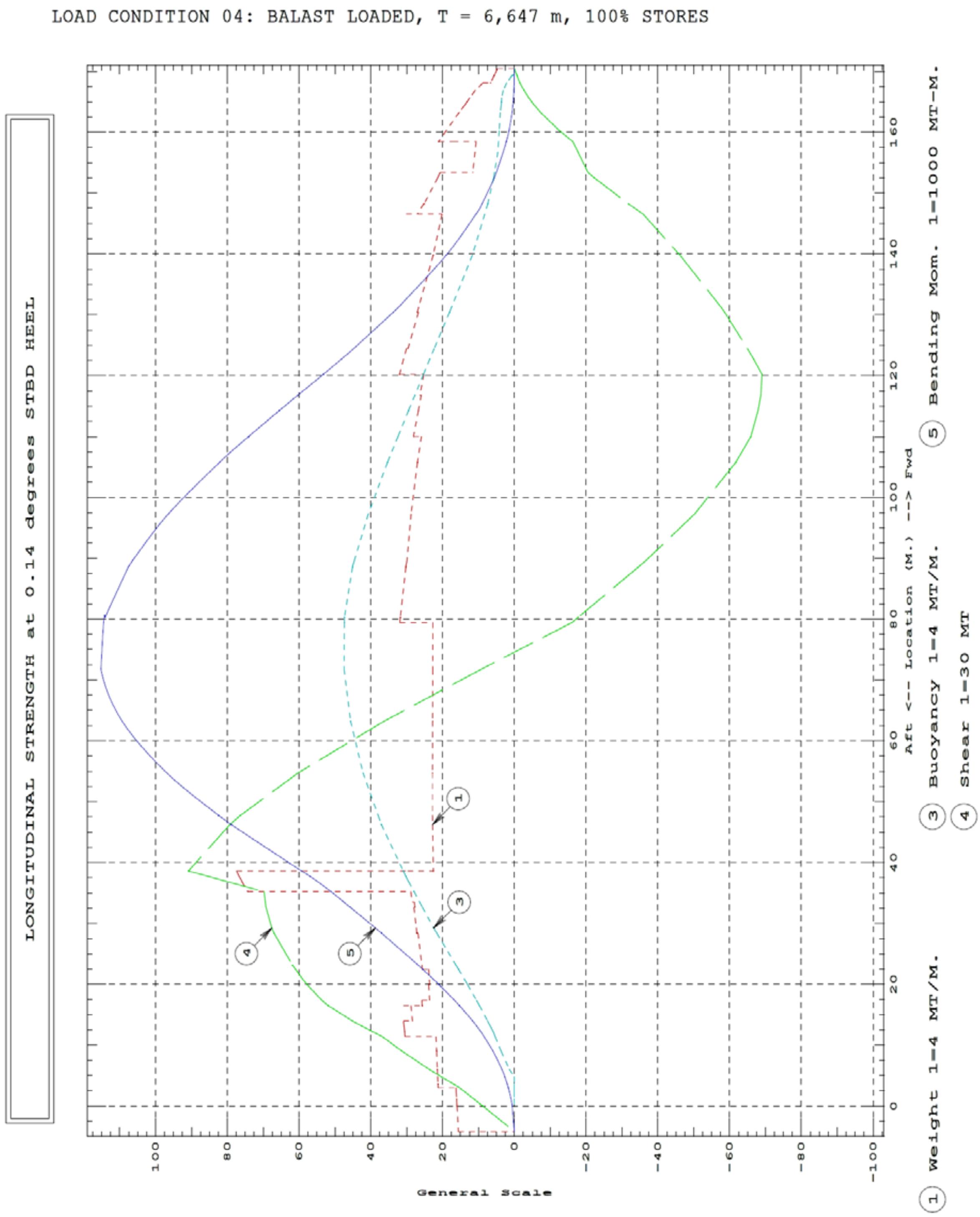
LOAD CONDITION 04: BALAST LOADED, T = 6,647 m, 100% STORES



Slika 39. Stanje krcanja 4 – karakteristike stabiliteta



Slika 40. Stanje krcanja 4 – karakteristike uzdužne čvrstoće

v. IMO rezolucija MSC.281(85)

MSC 85/26/Add.1

ANNEX 22

RESOLUTION MSC.281(85)
(adopted on 4 December 2008)

EXPLANATORY NOTES TO THE SOLAS CHAPTER II-1 SUBDIVISION AND DAMAGE STABILITY REGULATIONS

THE MARITIME SAFETY COMMITTEE,

RECALLING Article 28(b) of the Convention on the International Maritime Organization concerning the function of the Committee,

RECALLING ALSO that, by resolution MSC.216(82), it adopted the regulations on subdivision and damage stability as contained in SOLAS chapter II-1 which are based on the probabilistic concept, using the probability of survival after collision as a measure of ships' safety in a damaged condition,

NOTING that, at the eighty-second session, it approved Interim Explanatory Notes to the SOLAS chapter II-1 subdivision and damage stability regulations (MSC.1/Circ.1226), to assist Administrations in the uniform interpretation and application of the aforementioned subdivision and damage stability regulations,

BEING DESIROUS that definitive Explanatory Notes should be adopted when more experience in the application of the the aforementioned subdivision and damage stability regulations and the Interim Explanatory Notes had been gained,

RECOGNIZING that the appropriate application of the Explanatory Notes is essential for ensuring the uniform application of the SOLAS chapter II-1 subdivision and damage stability regulations,

HAVING CONSIDERED, at its eighty-fifth session, the recommendations made by the Sub-Committee on Stability and Load Lines and on Fishing Vessels Safety at its fifty-first session,

1. ADOPTS the Explanatory Notes to the SOLAS chapter II-1 subdivision and damage stability regulations set out in the Annex to the present resolution;

2. URGES Governments and all parties concerned to utilize the Explanatory Notes when applying the SOLAS chapter II-1 subdivision and damage stability regulations adopted by resolution MSC.216(82).

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EXPLANATORY NOTES TO THE SOLAS CHAPTER II-1 SUBDIVISION AND DAMAGE STABILITY REGULATIONS

Contents

PART A

INTRODUCTION

1 The harmonized SOLAS regulations on subdivision and damage stability, as contained in SOLAS chapter II-1, are based on a probabilistic concept which uses the probability of survival after collision as a measure of ships' safety in a damaged condition. This probability is referred to as the "attained subdivision index *A*" in the regulations. It can be considered an objective measure of ships' safety and, ideally, there would be no need to supplement this index by any deterministic requirements.

2 The philosophy behind the probabilistic concept is that two different ships with the same attained index are of equal safety and, therefore, there is no need for special treatment of specific parts of the ship, even if they are able to survive different damages. The only areas which are given special attention in the regulations are the forward and bottom regions, which are dealt with by special subdivision rules provided for cases of ramming and grounding.

3 Only a few deterministic elements, which were necessary to make the concept practicable, have been included. It was also necessary to include a deterministic "minor damage" on top of the probabilistic regulations for passenger ships to avoid ships being designed with what might be perceived as unacceptably vulnerable spots in some part of their length.

4 It is easily recognized that there are many factors that will affect the final consequences of hull damage to a ship. These factors are random and their influence is different for ships with different characteristics. For example, it would seem obvious that in ships of similar size carrying different amounts of cargo, damages of similar extents may lead to different results because of differences in the range of permeability and draught during service. The mass and velocity of the ramming ship is obviously another random variable.

5 Due to this, the effect of a three-dimensional damage to a ship with given watertight subdivision depends on the following circumstances:

.1 which particular space or group of adjacent spaces is flooded;

.2 the draught, trim and intact metacentric height at the time of damage;

.3 the permeability of affected spaces at the time of damage;

.4 the sea state at the time of damage; and

.5 other factors such as possible heeling moments due to unsymmetrical weights.

6 Some of these circumstances are interdependent and the relationship between them and their effects may vary in different cases. Additionally, the effect of hull strength on penetration will obviously have some effect on the results for a given ship. Since the location and size of the damage is random, it is not possible to state which part of the ship becomes flooded. However, the probability of flooding a given space can be determined if the probability of occurrence of certain damages is known from experience, that is, damage statistics. The probability of flooding a space is then equal to the probability of occurrence of all such damages which just open the considered space to the sea.

7 For these reasons and because of mathematical complexity as well as insufficient data, it would not be practicable to make an exact or direct assessment of their effect on the probability that a particular ship will survive a random damage if it occurs. However, accepting some approximations or qualitative judgments, a logical treatment may be achieved by using the probability approach as the basis for a comparative method for the assessment and regulation of ship safety.

8 It may be demonstrated by means of probability theory that the probability of ship survival should be calculated as the sum of probabilities of its survival after flooding each single compartment, each group of two, three, etc., adjacent compartments multiplied, respectively, by the probabilities of occurrence of such damages leading to the flooding of the corresponding compartment or group of compartments.

9 If the probability of occurrence for each of the damage scenarios the ship could be subjected to is calculated and then combined with the probability of surviving each of these damages with the ship loaded in the most probable loading conditions, we can determine the attained index A as a measure for the ship's ability to sustain a collision damage.

10 It follows that the probability that a ship will remain afloat without sinking or capsizing as a result of an arbitrary collision in a given longitudinal position can be broken down to:

.1 the probability that the longitudinal centre of damage occurs in just the region of the ship under consideration;

.2 the probability that this damage has a longitudinal extent that only includes spaces between the transverse watertight bulkheads found in this region;

.3 the probability that the damage has a vertical extent that will flood only the spaces below a given horizontal boundary, such as a watertight deck;

.4 the probability that the damage has a transverse penetration not greater than the distance to a given longitudinal boundary; and

.5 the probability that the watertight integrity and the stability throughout the flooding sequence is sufficient to avoid capsizing or sinking.

11 The first three of these factors are solely dependent on the watertight arrangement of the ship, while the last two depend on the ship's shape. The last factor also depends on the actual loading condition. By grouping these probabilities, calculations of the probability of survival, or attained index A, have been formulated to include the following probabilities:

.1 the probability of flooding each single compartment and each possible group of two or more adjacent compartments; and

.2 the probability that the stability after flooding a compartment or a group of two or more adjacent compartments will be sufficient to prevent capsizing or dangerous heeling due to loss of stability or to heeling moments in intermediate or final stages of flooding.

12 This concept allows a rule requirement to be applied by requiring a minimum value of A for a particular ship. This minimum value is referred to as the "required subdivision index R" in the present regulations and can be made dependent on ship size, number of passengers or other factors legislators might consider important.

13 Evidence of compliance with the rules then simply becomes:

$$A \geq R$$

13.1 As explained above, the attained subdivision index A is determined by a formula for the entire probability as the sum of the products for each compartment or group of compartments of the probability that a space is flooded, multiplied by the probability that the ship will not capsize or sink due to flooding of the considered space. In other words, the general formula for the attained index can be given in the form:

$$A = \Sigma p_i s_i$$

13.2 Subscript "i" represents the damage zone (group of compartments) under consideration within the watertight subdivision of the ship. The subdivision is viewed in the longitudinal direction, starting with the aftmost zone/compartment.

13.3 The value of "p_i" represents the probability that only the zone "i" under consideration will be flooded, disregarding any horizontal subdivision, but taking transverse subdivision into account. Longitudinal subdivision within the zone will result in additional flooding scenarios, each with its own probability of occurrence.

13.4 The value of "s_i" represents the probability of survival after flooding the zone "i" under consideration.

14 Although the ideas outlined above are very simple, their practical application in an exact manner would give rise to several difficulties if a mathematically perfect method was to be developed. As pointed out above, an extensive but still incomplete description of the damage will include its longitudinal and vertical location as well as its longitudinal, vertical and transverse extent. Apart from the difficulties in handling such a five-dimensional random variable, it is impossible to determine its probability distribution very accurately with the presently available damage statistics. Similar limitations are true for the variables and physical relationships involved in the calculation of the probability that a ship will not capsize or sink during intermediate stages or in the final stage of flooding.

15 A close approximation of the available statistics would result in extremely numerous and complicated computations. In order to make the concept practicable, extensive simplifications are necessary. Although it is not possible to calculate the exact probability of survival on such a simplified basis, it has still been possible to develop a useful comparative measure of the merits of the longitudinal, transverse and horizontal subdivision of a ship.

PART B

GUIDANCE ON INDIVIDUAL SOLAS CHAPTER II-1 SUBDIVISION AND DAMAGE STABILITY REGULATIONS

REGULATION 1 – APPLICATION

Regulation 1.3

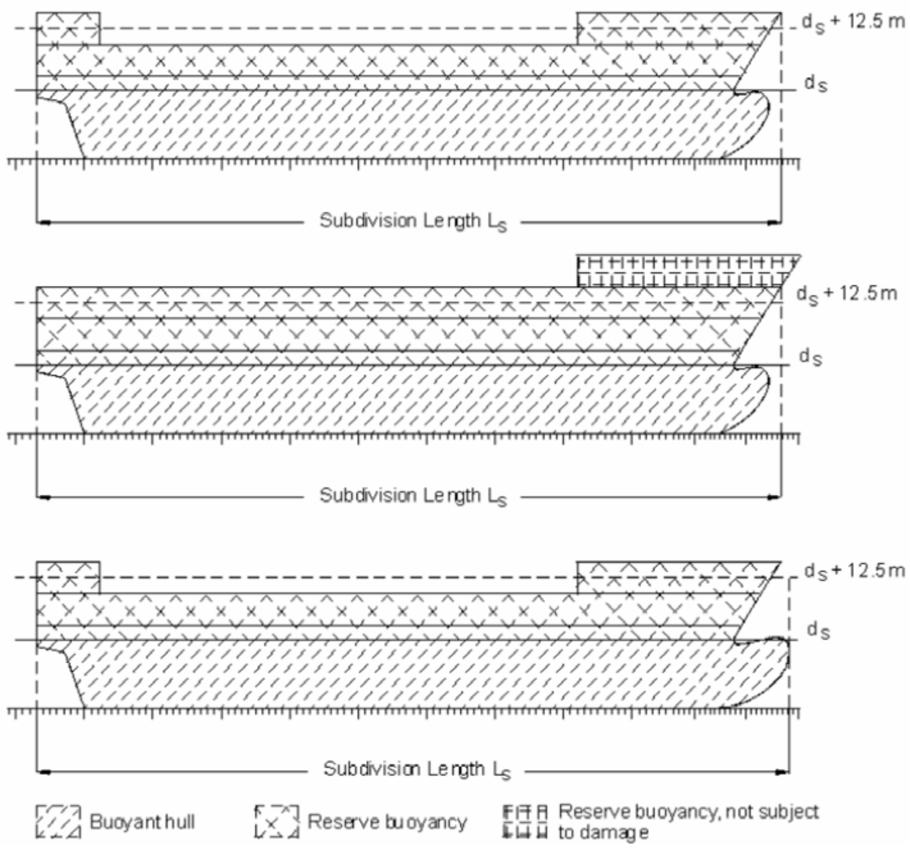
If a passenger ship built before 1 January 2009 undergoes alterations or modifications of major character, it may still remain under the damage stability regulations applicable to ships built before 1 January 2009, except in the case of a cargo ship being converted to a passenger ship.

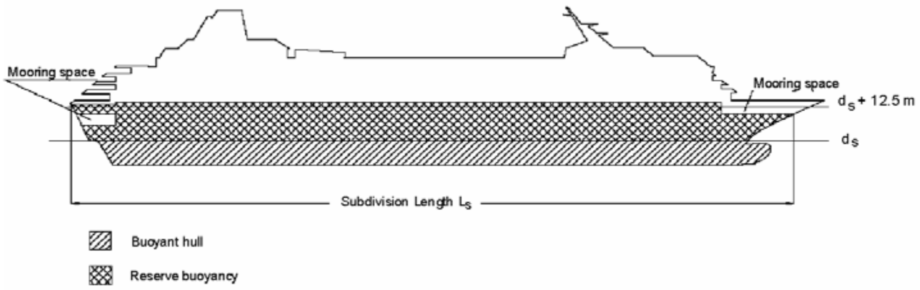
REGULATION 2 – DEFINITIONS

Regulation 2.1

Subdivision length (L_s) – Different examples of L_s showing the buoyant hull and the reserve buoyancy are provided in the figures below. The limiting deck for the reserve buoyancy may be partially watertight.

The maximum possible vertical extent of damage above the baseline is d_s + 12.5 metres.





Regulation 2.6

Freeboard deck – See Explanatory Notes for regulation 13-1* for the treatment of a stepped freeboard deck with regard to watertightness and construction requirements.

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* References to regulations in these Guidelines are to regulations of SOLAS chapter II-1, unless expressly provided otherwise.

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ANNEX 22
Page 8

Regulation 2.11

Light service draught (d_l) – The light service draught (d_l) represents the lower draught limit of the minimum required *GM* (or maximum allowable *KG*) curve. It corresponds, in general, to the ballast arrival condition with 10% consumables for cargo ships. For passenger ships, it corresponds, in general, to the arrival condition with 10% consumables, a full complement of passengers and crew and their effects, and ballast as necessary for stability and trim. The 10% arrival condition is not necessarily the specific condition that should be used for all ships, but represents, in general, a suitable lower limit for all loading conditions. This is understood to not include docking conditions or other non-voyage conditions.

Regulation 2.19

Bulkhead deck – See Explanatory Notes for regulation 13 for the treatment of a stepped bulkhead deck with regard to watertightness and construction requirements.

REGULATION 4 – GENERAL

Regulation 4.1

Cargo ships complying with the subdivision and damage stability regulations of other IMO instruments listed in the footnote are not required to comply with part B-1, regulations 6, 7, 7-1, 7-2 and 7-3, but should comply with the regulations indicated in the table below.

Regulation	Applies
Part B-1	
5	X
5-1	X
Part B-2	
9	X[(1)]
10	X
11	X
12	X
13-1	X
15	X
15-1	X
16	X
16-1	X
Part B-4	
19	X
22	X
24	X
25	X[(2)]

(1) Only applies to cargo ships other than tankers.
(2) Only applies to single hold cargo ships other than bulk carriers.

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Regulation 4.1, footnote .1

"OBO ships" means *combination carriers* as defined in SOLAS regulation II-2/3.14.

Regulation 4.4

See Explanatory Notes for regulation 7-2.2, for information and guidance related to these provisions.

REGULATION 5 – INTACT STABILITY INFORMATION

Reference is made to MSC/Circ.1158 (Unified interpretation of SOLAS chapter II-1) regarding lightweight check.

REGULATION 5-1 – STABILITY INFORMATION TO BE SUPPLIED TO THE MASTER

Regulation 5-1.2

Any limiting *GM* (or *KG*) requirements arising from provisions in regulation 6.1 (regarding partial attained subdivision indices), regulation 8 or regulation 9, which are in addition to those described in regulation 5-1.4, should also be taken into account when developing this information.

Regulations 5-1.3 and 5-1.4 (see also regulation 7.2)

1 Linear interpolation of the limiting values between the draughts d_s, d_p and d_l is only applicable to minimum *GM* values. If it is intended to develop curves of maximum permissible *KG*, a sufficient number of KM_T values for intermediate draughts should be calculated to ensure that the resulting maximum *KG* curves correspond with a linear variation of *GM*. When light service draught is not with the same trim as other draughts, KM_T for draughts between partial and light service draught should be calculated for trims interpolated between trim at partial draught and trim at light service draught.

2 In cases where the operational trim range is intended to exceed ±0.5% of L_s, the original *GM* limit line should be designed in the usual manner with the deepest subdivision draught and partial subdivision draught calculated at level trim and actual service trim used for the light service draught. Then additional sets of *GM* limit lines should be constructed on the basis of the operational range of trims which is covered by loading conditions of partial subdivision draught and deepest subdivision draught ensuring that intervals of 1% L_s are not exceeded. For the light service draught d_l only one trim should be considered. The sets of *GM* limit lines are combined to give one envelope limiting *GM* curve. The effective trim range of the curve should be clearly stated.

REGULATION 6 – REQUIRED SUBDIVISION INDEX *R*

Regulation 6.1

To demonstrate compliance with these provisions, see the Guidelines for the preparation of subdivision and damage stability calculations, set out in the appendix, regarding the presentation of damage stability calculation results.

Regulation 6.2.4

Regarding the term "reduced degree of hazard", the following interpretation should be applied: A lesser value of N, but in no case less than $N = N_1 + N_2$, may be allowed at the discretion of the Administration for passenger ships, which, in the course of their voyages, do not proceed more than 20 miles from the nearest land.

REGULATION 7 – ATTAINED SUBDIVISION INDEX *A*

Regulation 7.1

1 The probability of surviving after collision damage to the ship's hull is expressed by the index A. Producing an index A requires calculation of various damage scenarios defined by the extent of damage and the initial loading conditions of the ship before damage. Three loading conditions should be considered and the result weighted as follows:

$$A = 0.4A_s + 0.4A_p + 0.2A_l$$

where the indices s, p and l represent the three loading conditions and the factor to be multiplied to the index indicates how the index A from each loading condition is weighted.

2 The method of calculating A for a loading condition is expressed by the formula:

$$A_c = \sum_{i=1}^{i=t} p_i \left[v_i s_i \right]$$

2.1 The index c represents one of the three loading conditions, the index i represents each investigated damage or group of damages and t is the number of damages to be investigated to calculate A_c for the particular loading condition.

2.2 To obtain a maximum index A for a given subdivision, t has to be equal to T, the total number of damages.

3 In practice, the damage combinations to be considered are limited either by significantly reduced contributions to A (i.e. flooding of substantially larger volumes) or by exceeding the maximum possible damage length.

4 The index A is divided into partial factors as follows:

p_i The p factor is solely dependent on the geometry of the watertight arrangement of the ship.

v_i The v factor is dependent on the geometry of the watertight arrangement (decks) of the ship and the draught of the initial loading condition. It represents the probability that the spaces above the horizontal subdivision will not be flooded.

s_i The s factor is dependent on the calculated survivability of the ship after the considered damage for a specific initial condition.

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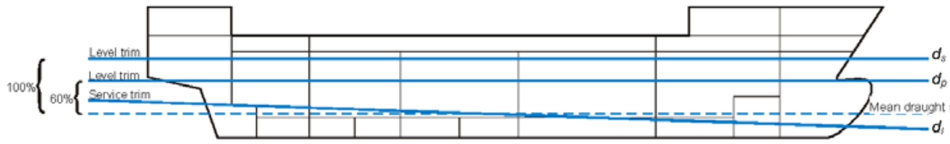
5 Three initial loading conditions should be used for calculating the index A. The loading conditions are defined by their mean draught d, trim and GM (or KG). The mean draught and trim are illustrated in the figure below.



6 The GM (or KG) values for the three loading conditions could, as a first attempt, be taken from the intact stability GM (or KG) limit curve. If the required index R is not obtained, the GM (or KG) values may be increased (or reduced), implying that the intact loading conditions from the intact stability book must now meet the GM (or KG) limit curve from the damage stability calculations derived by linear interpolation between the three GMs.

Regulation 7.2

1 The calculations for differing trim should be carried out with the same initial trim for the partial and deepest subdivision draughts. For the light service draught, the actual service trim should be used (refer to the Explanatory Notes for regulation 2.11).

2 Each combination of the index within the formula given in regulation 7.1 should not be less than the requirement given in regulation 6.2. Each partial index A should comply with the requirements of regulation 6.1.

3 Example:

Based on the GM limiting curves obtained from damage stability calculations of each trim, an envelope curve covering all calculated trim values should be developed.

Calculations covering different trim values should be carried out in steps not exceeding 1% of L_s. The whole range including intermediate trims should be covered by the damage stability calculations. Refer to the example showing an envelope curve obtained from calculations of 0 trim and 1% of L_s.

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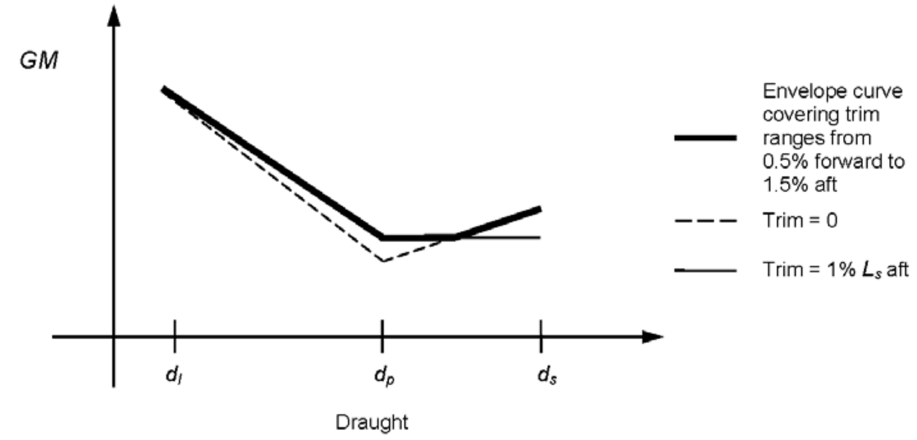


Regulation 7.5

1 With the same intent as wing tanks, the summation of the attained index *A* should reflect effects caused by all watertight bulkheads and flooding boundaries within the damaged zone. It is not correct to assume damage only to the centreline and ignore changes in subdivision that would reflect lesser contributions.

2 In the forward and aft ends of the ship where the sectional breadth is less than the ship's breadth *B*, transverse damage penetration can extend beyond the centreline bulkhead. This application of the transverse extent of damage is consistent with the methodology to account for the localized statistics which are normalized on the greatest moulded breadth *B* rather than the local breadth.

3 Where longitudinal corrugated bulkheads are fitted in wing compartments or on the centreline, they may be treated as equivalent plane bulkheads provided the corrugation depth is of the same order as the stiffening structure. The same principle may also be applied to transverse corrugated bulkheads.

Regulation 7.7

1 Pipes and valves directly adjacent to a bulkhead or to a deck can be considered to be part of the bulkhead or deck, provided the separation distance is of the same order as the bulkhead or deck stiffening structure. The same applies for small recesses, drain wells, etc.

2 The provision for allowing "minor progressive flooding" should be limited to pipes penetrating a watertight subdivision with a total cross-sectional area of not more than 710 mm^2 between any two watertight compartments.

REGULATION 7-1 – CALCULATION OF THE FACTOR p_i

General

1 The definitions below are intended to be used for the application of part B-1 only.

2 In regulation 7-1, the words "compartment" and "group of compartments" should be understood to mean "zone" and "adjacent zones".

3 Zone – a longitudinal interval of the ship within the subdivision length.

4 Room – a part of the ship, limited by bulkheads and decks, having a specific permeability.

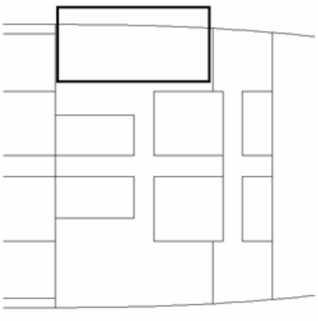
5 Space – a combination of rooms.

6 Compartment – an onboard space within watertight boundaries.

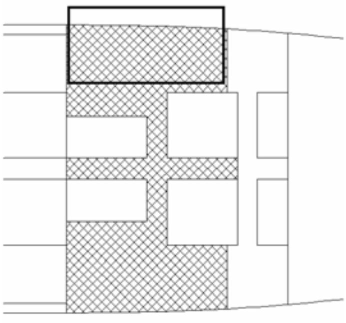
7 Damage – the three dimensional extent of the breach in the ship.

8 For the calculation of p, v, r and b only the damage should be considered, for the calculation of the s-value the flooded space should be considered. The figures below illustrate the difference.

Damage shown as the bold square:



Flooded space shown below:



Regulation 7-1.1.1

1 The coefficients b_{11}, b_{12}, b_{21} and b_{22} are coefficients in the bi-linear probability density function on normalized damage length (J). The coefficient b_{12} is dependent on whether L_s is greater or less than L^* (i.e. 260 m); the other coefficients are valid irrespective of L_s.

Longitudinal subdivision

2 In order to prepare for the calculation of index A, the ship's subdivision length L_s is divided into a fixed discrete number of damage zones. These damage zones will determine the damage stability investigation in the way of specific damages to be calculated.

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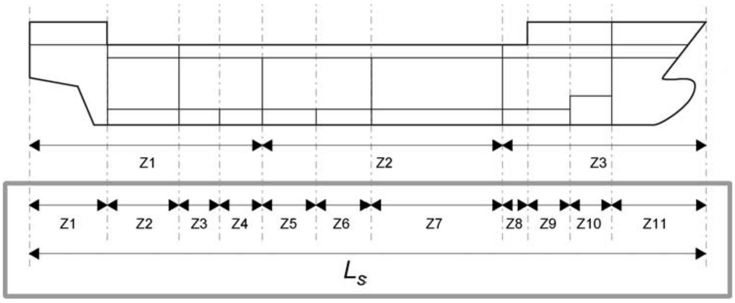
3 There are no rules for the subdividing, except that the length L_s defines the extremes for the actual hull. Zone boundaries need not coincide with physical watertight boundaries. However, it is important to consider a strategy carefully to obtain a good result (that is a large attained index A). All zones and combination of adjacent zones may contribute to the index A. In general it is expected that the more zone boundaries the ship is divided into the higher will be the attained index, but this benefit should be balanced against extra computing time. The figure below shows different longitudinal zone divisions of the length L_s.



4 The first example is a very rough division into three zones of approximately the same size with limits where longitudinal subdivision is established. The probability that the ship will survive a damage in one of the three zones is expected to be low (i.e. the s-factor is low or zero) and, therefore, the total attained index A will be correspondingly low.

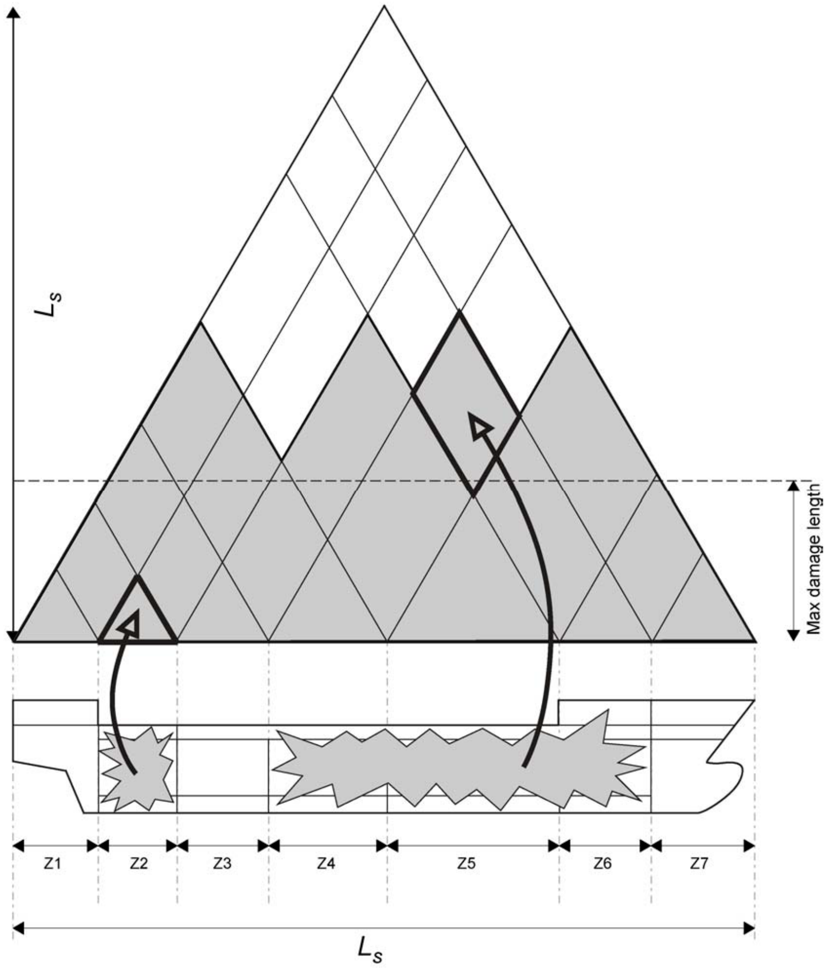
5 In the second example the zones have been placed in accordance with the watertight arrangement, including minor subdivision (as in double bottom, etc.). In this case there is a much better chance of obtaining higher s-factors.

6 Where transverse corrugated bulkheads are fitted, they may be treated as equivalent plane bulkheads, provided the corrugation depth is of the same order as the stiffening structure.

7 Pipes and valves directly adjacent to a transverse bulkhead can be considered to be part of the bulkhead, provided the separation distance is of the same order as the bulkhead stiffening structure. The same applies for small recesses, drain wells, etc.

8 For cases where the pipes and valves are outside the transverse bulkhead stiffening structure, when they present a risk of progressive flooding to other watertight compartments that will have influence on the overall attained index A, they should be handled either by introducing a new damage zone and accounting for the progressive flooding to associated compartments or by introducing a gap.

9 The triangle in the figure below illustrates the possible single and multiple zone damages in a ship with a watertight arrangement suitable for a seven-zone division. The triangles at the bottom line indicate single zone damages and the parallelograms indicate adjacent zones damages.



10 As an example, the triangle illustrates a damage opening the rooms in zone 2 to the sea and the parallelogram illustrates a damage where rooms in the zones 4, 5 and 6 are flooded simultaneously.

11 The shaded area illustrates the effect of the maximum absolute damage length. The p-factor for a combination of three or more adjacent zones equals zero if the length of the combined adjacent damage zones minus the length of the foremost and the aft most damage zones in the combined damage zone is greater than the maximum damage length. Having this in mind when subdividing L_s could limit the number of zones defined to maximize the attained index A.

12 As the p-factor is related to the watertight arrangement by the longitudinal limits of damage zones and the transverse distance from the ship side to any longitudinal barrier in the zone, the following indices are introduced:

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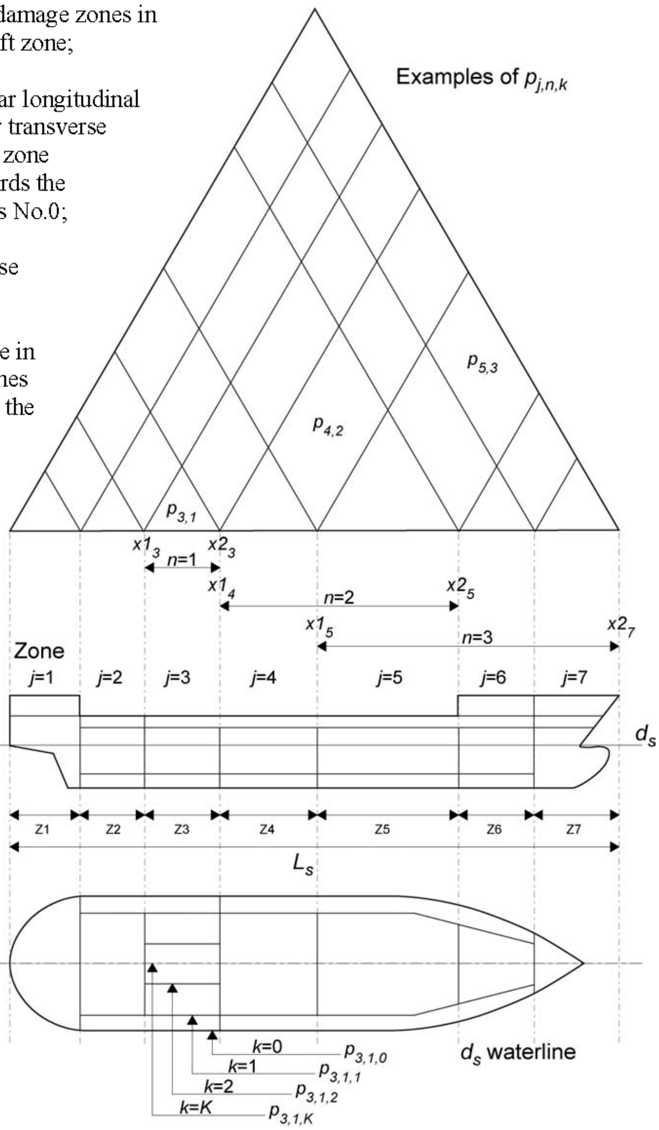
j: the damage zone number starting with No.1 at the stern;

n: the number of adjacent damage zones in question where *j* is the aft zone;

k: the number of a particular longitudinal bulkhead as a barrier for transverse penetration in a damage zone counted from shell towards the centreline. The shell has No.0;

K: total number of transverse penetration boundaries;

$p_{j,n,k}$: the *p*-factor for a damage in zone *j* and next (*n*-1) zones forward of *j* damaged to the longitudinal bulkhead *k*.



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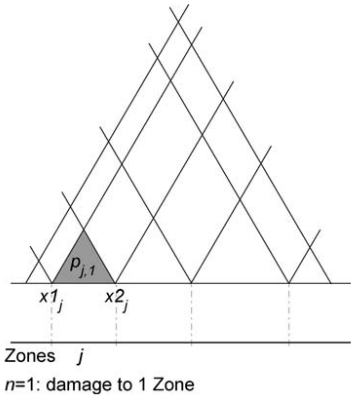
Pure longitudinal subdivision

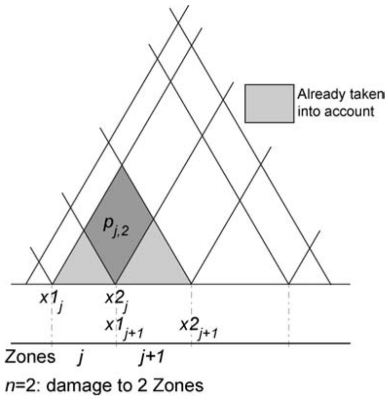
Single damage zone, pure longitudinal subdivision:

$$p_{j,1} = p(x1_j, x2_j)$$



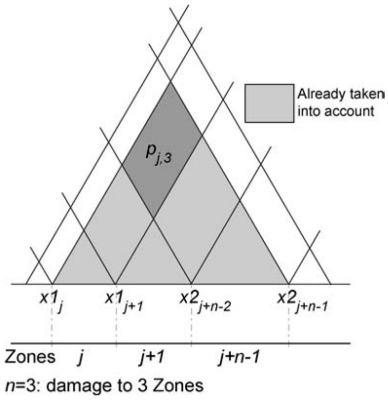
Two adjacent zones, pure longitudinal subdivision:

$$p_{j,2} = p(x1_j, x2_{j+1}) - p(x1_j, x2_j) - p(x1_{j+1}, x2_{j+1})$$



Three or more adjacent zones, pure longitudinal subdivision:

$$p_{j,n} = p(x1_j, x2_{j+n-1}) - p(x1_j, x2_{j+n-2}) - p(x1_{j+1}, x2_{j+n-1}) + p(x1_{j+1}, x2_{j+n-2})$$



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Regulation 7-1.1.2

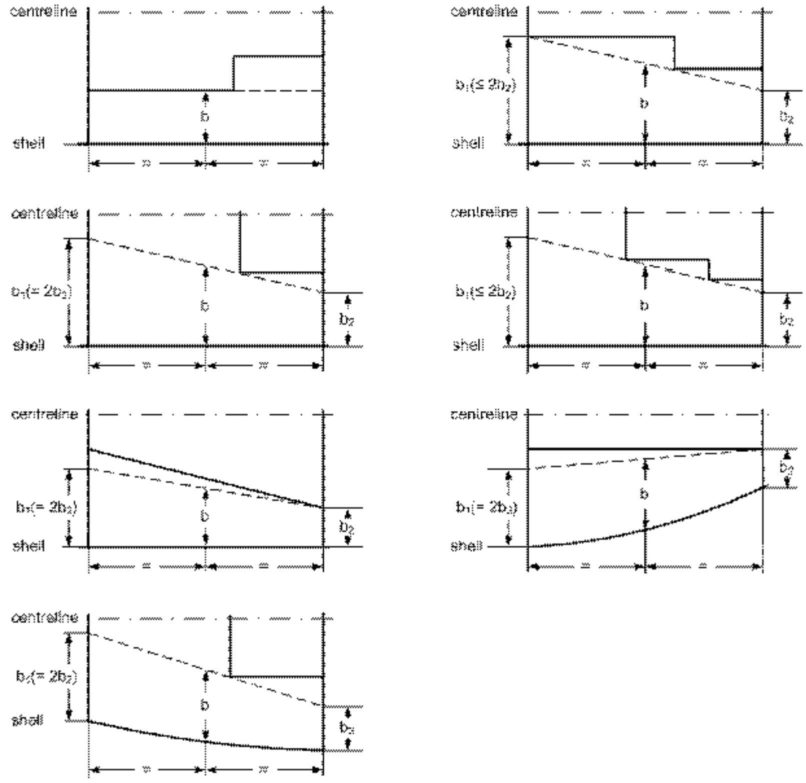
Transverse subdivision in a damage zone

1 Damage to the hull in a specific damage zone may just penetrate the ship's watertight hull or penetrate further towards the centreline. To describe the probability of penetrating only a wing compartment, a probability factor r is used, based mainly on the penetration depth b. The value of r is equal to 1, if the penetration depth is $B/2$ where B is the maximum breadth of the ship at the deepest subdivision draught d_s, and $r = 0$ if $b = 0$.

2 The penetration depth b is measured at level deepest subdivision draught d_s as a transverse distance from the ship side right-angled to the centreline to a longitudinal barrier.

3 Where the actual watertight bulkhead is not a plane parallel to the shell, b should be determined by means of an assumed line, dividing the zone to the shell in a relationship b_1/b_2 with $1/2 \leq b_1/b_2 \leq 2$.

4 Examples of such assumed division lines are illustrated in the figure below. Each sketch represents a single damage zone at a water line plane level d_s and the longitudinal bulkhead represents the outermost bulkhead position below d_s + 12.5 m.



5 In calculating *r*-values for a group of two or more adjacent compartments, the *b*-value is common for all compartments in that group, and equal to the smallest *b*-value in that group:

$$b = \min\{b_1, b_2, \ldots, b_n\}$$

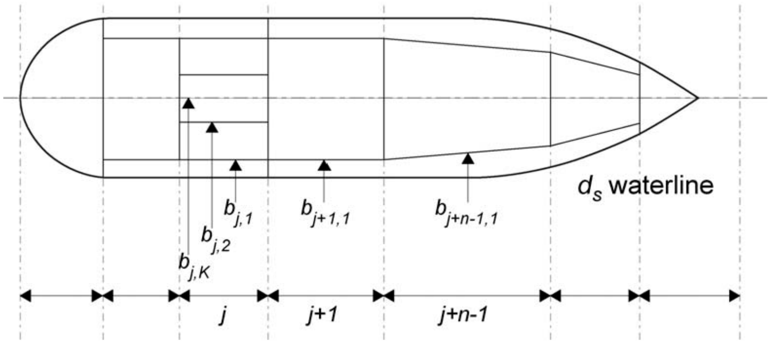
where: $n =$ number of wing compartments in that group;
$b_1, b_2, \ldots, b_n =$ mean values of b for individual wing compartments contained in the group.

Accumulating p

6 The accumulated value of *p* for one zone or a group of adjacent zones is determined by:

$$p_{j,n} = \sum_{k=1}^{k=K_{j,n}} p_{j,n,k}$$

where $K_{j,n} = \sum_{j}^{j+n-1} K_j$ the total number of b_k's for the adjacent zones in question.



7 The figure above illustrates *b*'s for adjacent zones. The zone *j* has two penetration limits and one to the centre, the zone *j+1* has one *b* and the zone *j+n-1* has one value for *b*. The multiple zones will have (2+1+1) four values of *b*, and sorted in increasing order they are:

$(b_{j,1} ; b_{j+1,1} ; b_{j+n-1,1} ; b_{j,2} ; b_K)$

8 Because of the expression for *r(x1, x2, b)* only one b_K should be considered. To minimize the number of calculations, *b*'s of the same value may be deleted.

As $b_{j,1} = b_{j+1,1}$ the final *b*'s will be $(b_{j,1} ; b_{j+n-1,1} ; b_{j,2} ; b_K)$

Examples of multiple zones having a different b

9 Examples of combined damage zones and damage definitions are given in the figures below. Compartments are identified by R10, R12, etc.

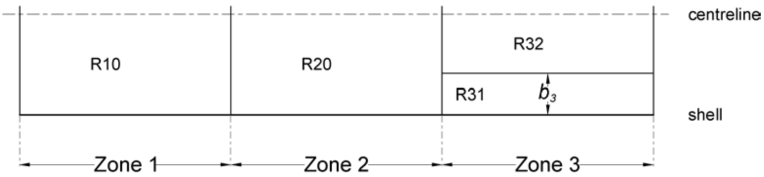


Figure: Combined damage of zones 1 + 2 + 3 includes a limited penetration to b_3, taken into account generating two damages:

1) to b_3 with R10, R20 and R31 damaged;
2) to *B/2* with R10, R20, R31 and R32 damaged.

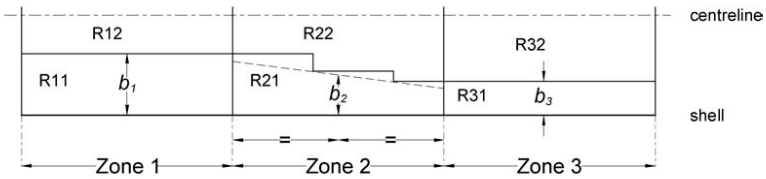


Figure: Combined damage of zones 1 + 2 + 3 includes 3 different limited damage penetrations generating four damages:

1) to b_3 with R11, R21 and R31 damaged;
2) to b_2 with R11, R21, R31 and R32 damaged;
3) to b_1 with R11, R21, R31, R32, and R22 damaged;
4) to *B/2* with R11, R21, R31, R32, R22 and R12 damaged.

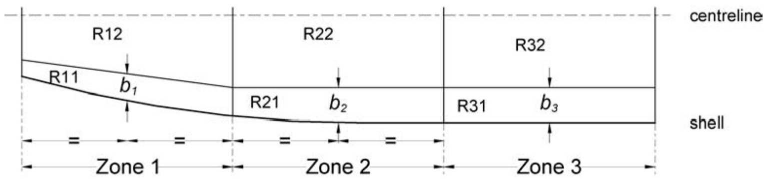
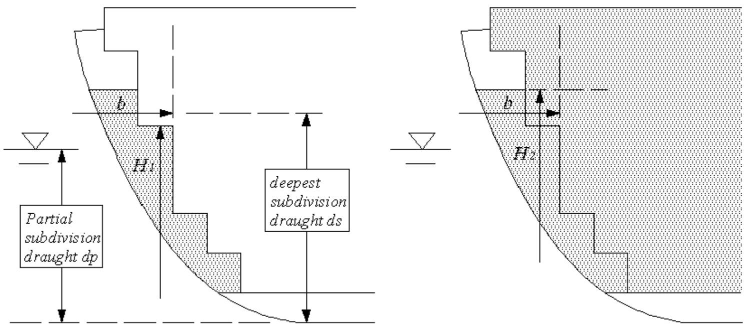


Figure: Combined damage of zone 1 + 2 + 3 including 2 different limited damage penetrations ($b_1 < b_2 = b_3$) generating three damages:

1) to b_1 with R11, R21 and R31 damaged;
2) to b_2 with R11, R21, R31 and R12, damaged;
3) to *B/2* with R11, R21, R31, R12, R22 and R32 damaged.

10 A damage having a transverse extent b and a vertical extent H_2 leads to the flooding of both wing compartment and hold; for b and H_1 only the wing compartment is flooded. The figure below illustrates a partial subdivision draught d_p damage.



11 The same is valid if b-values are calculated for arrangements with sloped walls.

12 Pipes and valves directly adjacent to a longitudinal bulkhead can be considered to be part of the bulkhead, provided the separation distance is of the same order as the bulkhead stiffening structure. The same applies for small recesses, drain wells, etc.

REGULATION 7-2 – CALCULATION OF THE FACTOR s_i

General

1 Initial condition – an intact loading condition to be considered in the damage analysis described by the mean draught, vertical centre of gravity and the trim; or alternative parameters from where the same may be determined (ex. displacement, *GM* and trim). There are three initial conditions corresponding to the three draughts d_s, d_p and d_l.

2 Immersion limits – immersion limits are an array of points that are not to be immersed at various stages of flooding as indicated in regulations 7-2.5.2 and 7-2.5.3.

3 Openings – all openings need to be defined: both weathertight and unprotected. Openings are the most critical factor to preventing an inaccurate index *A*. If the final waterline immerses the lower edge of any opening through which progressive flooding takes place, the factor "*s*" may be recalculated taking such flooding into account. However, in this case the *s* value should also be calculated without taking into account progressive flooding and corresponding opening. The smallest *s* value should be retained for the contribution to the attained index.

Regulation 7-2.1

1 In cases where the *GZ* curve may include more than one "range" of positive righting levers for a specific stage of flooding, only one continuous positive "range" of the *GZ* curve may be used within the allowable range/heel limits for calculation purposes. Different stages of flooding may not be combined in a single *GZ* curve.

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Figure 1

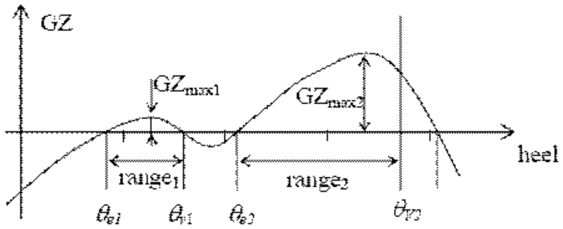
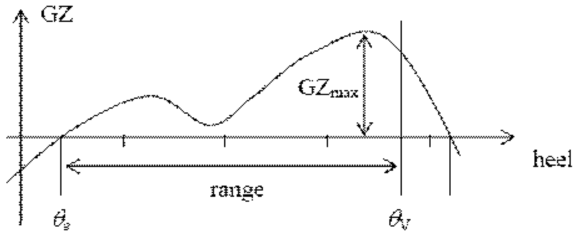


Figure 2



2 In figure 1, the *s*-factor may be calculated from the heel angle, range and corresponding GZ_{max} of the first or second "range" of positive righting levers. In figure 2, only one *s*-factor can be calculated.

Regulation 7-2.2

Intermediate stages of flooding

1 The case of instantaneous flooding in unrestricted spaces in way of the damage zone does not require intermediate stage flooding calculations. Where intermediate stages of flooding calculations are necessary in connection with progressive flooding, they should reflect the sequence of filling as well as filling level phases. Calculations for intermediate stages of flooding should be performed whenever equalization is not instantaneous, i.e. equalization is of a duration greater than 60 s. Such calculations consider the progress through one or more floodable (non-watertight) spaces. Bulkheads surrounding refrigerated spaces, incinerator rooms and longitudinal bulkheads fitted with non-watertight doors are typical examples of structures that may significantly slow down the equalization of main compartments.

Flooding boundaries

2 If a compartment contains decks, inner bulkheads, structural elements and doors of sufficient tightness and strength to seriously restrict the flow of water, for intermediate stage flooding calculation purposes it should be divided into corresponding non-watertight spaces. It is assumed that the non-watertight divisions considered in the calculations are limited to "A" class fire-rated bulkheads and do not apply to "B" class fire-rated bulkheads normally used in accommodation areas (e.g., cabins and corridors). This guidance also relates to regulation 4.4.

Sequential flooding computation

3 For each damage scenario, the damage extent and location determine the initial stage of flooding. Calculations should be performed in stages, each stage comprising of at least two intermediate filling phases in addition to the full phase per flooded space. Unrestricted spaces in way of damage should be considered as flooded immediately. Every subsequent stage involves all connected spaces being flooded simultaneously until an impermeable boundary or final equilibrium is reached. If due to the configuration of the subdivision in the ship it is expected that other intermediate stages of flooding are more onerous, then those should be investigated.

Cross-flooding/equalization

4 In general, cross-flooding is meant as a flooding of an undamaged space on the other side of the ship to reduce the heel in the final equilibrium condition.

5 The cross-flooding time should be calculated in accordance with the Recommendation on a standard method for evaluating cross-flooding arrangements (resolution MSC.245(83)). If complete fluid equalization occurs in 60 s or less, it should be treated as instantaneous and no further calculations need to be carried out. Additionally, in cases where $s_{final} = 1$ is achieved in 60 s or less, but equalization is not complete, instantaneous flooding may also be assumed if s_{final} will not become reduced. In any cases where complete fluid equalization exceeds 60 s, the value of $s_{intermediate}$ after 60 s is the first intermediate stage to be considered. Only passive open cross-flooding arrangements without valves should be considered effective for instantaneous flooding cases.

6 If complete fluid equalization can be finalized in 10 min or less, the assessment of survivability can be carried out for passenger ships as the smallest values of $s_{intermediate}$ or s_{final}.

7 In case the equalization time is longer than 10 min, s_{final} is calculated for the floating position achieved after 10 min of equalization. This floating position is computed by calculating the amount of flood water according to resolution MSC.245(83) using interpolation, where the equalization time is set to 10 min, i.e. the interpolation of the flood water volume is made between the case before equalization ($T = 0$) and the total calculated equalization time.

8 In any cases where complete fluid equalization exceeds 10 min, the value of s_{final} used in the formula in regulation 7-2.1.1 should be the minimum of s_{final} at 10 min or at final equalization.

Cargo ships

9 If the Administration considers that the stability in intermediate stages of flooding in a cargo ship may be insufficient, it may require further investigation thereof.

Regulation 7-2.4

The displacement is the intact displacement at the subdivision draught in question (d_s, d_p and d_l).

Regulation 7-2.4.1.1

The beam B used in this paragraph means breadth as defined in regulation 2.8.

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Regulation 7-2.4.1.2

The parameter *A* (projected lateral area) used in this paragraph does not refer to the attained subdivision index.

Regulation 7-2.5

In cargo ships where cross-flooding devices are fitted, the safety of the ship should be maintained in all stages of flooding. The Administration may request for this to be demonstrated. Cross-flooding equipment, if installed, should have the capacity to ensure that the equalization takes place within 10 min.

Regulation 7-2.5.2.1

Unprotected openings

1 The flooding angle will be limited by immersion of such an opening. It is not necessary to define a criterion for non-immersion of unprotected openings at equilibrium, because if it is immersed, the range of positive *GZ* limited to flooding angle will be zero so "*s*" will be equal to zero.

2 An unprotected opening connects two rooms or one room and the outside. An unprotected opening will not be taken into account if the two connected rooms are flooded or none of these rooms are flooded. If the opening is connected to the outside, it will not be taken into account if the connected compartment is flooded. An unprotected opening does not need to be taken into account if it connects a flooded room or the outside to an undamaged room, if this room will be considered as flooded in a subsequent stage.

Openings fitted with a weathertight mean of closing ("weathertight openings")

3 The survival "*s*" factor will be "0" if any such point is submerged at a stage which is considered as "final". Such points may be submerged during a stage or phase which is considered as "intermediate", or within the range beyond equilibrium.

4 If an opening fitted with a weathertight means of closure is submerged at equilibrium during a stage considered as intermediate, it should be demonstrated that this weathertight means of closure can sustain the corresponding head of water and that the leakage rate is negligible.

5 These points are also defined as connecting two rooms or one room and the outside, and the same principle as for unprotected openings is applied to take them into account or not. If several stages have to be considered as "final", a "weathertight opening" does not need to be taken into account if it connects a flooded room or the outside to an undamaged room if this room will be considered as flooded in a successive "final" stage.

Regulation 7-2.5.2.2

1 Partial immersion of the bulkhead deck may be accepted at final equilibrium. This provision is intended to ensure that evacuation along the bulkhead deck to the vertical escapes will not be impeded by water on that deck. A "horizontal evacuation route" in the context of this regulation means a route on the bulkhead deck connecting spaces located on and under this deck with the vertical escapes from the bulkhead deck required for compliance with SOLAS chapter II-2.

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2 Horizontal evacuation routes on the bulkhead deck include only escape routes (designated as category 2 stairway spaces according to SOLAS regulation II-2/9.2.2.3 or as category 4 stairway spaces according to SOLAS regulation II-2/9.2.2.4 for passenger ships carrying not more than 36 passengers) used for the evacuation of undamaged spaces. Horizontal evacuation routes do not include corridors (designated as category 3 corridor spaces according to SOLAS regulation II-2/9.2.2.3 or as category 2 corridor spaces according to SOLAS regulation II-2/9.2.2.4 for passenger ships carrying not more than 36 passengers) within the damaged space. No part of a horizontal evacuation route serving undamaged spaces should be immersed.

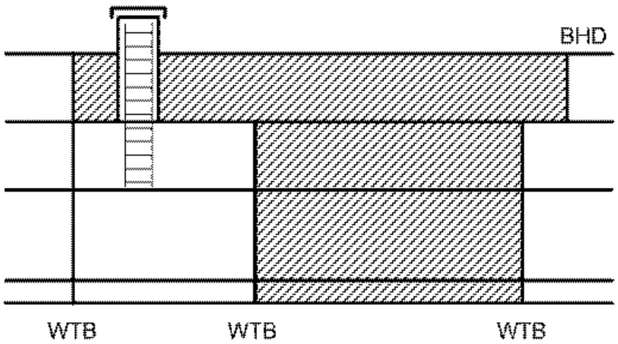
3 $s_i = 0$ where it is not possible to access a stair leading up to the embarkation deck from an undamaged space as a result of flooding to the "stairway" or "horizontal stairway" on the bulkhead deck.

4 Horizontal escapes situated in way of the damage extent may remain effective, therefore s_i need not be taken as zero. Contributions to the attained index A may still be gained.

Regulation 7-2.5.3.1

1 The purpose of this paragraph is to provide an incentive to ensure that evacuation through a vertical escape will not be obstructed by water from above. The paragraph is intended for smaller emergency escapes, typically hatches, where fitting of a watertight or weathertight means of closure would otherwise exclude them from being considered as flooding points.

2 Since the probabilistic regulations do not require that the watertight bulkheads be carried continuously up to the bulkhead deck, care should be taken to ensure that evacuation from intact spaces through flooded spaces below the bulkhead deck will remain possible, for instance by means of a watertight trunk.



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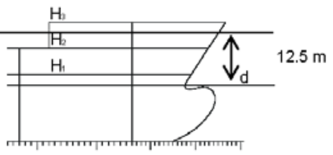
Regulation 7-2.6

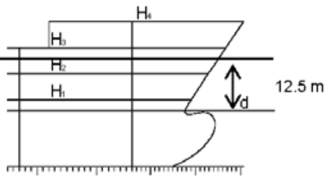
The sketches in the figure illustrate the connection between position of watertight decks in the reserve buoyancy area and the use of factor v for damages below these decks.

Above the waterline



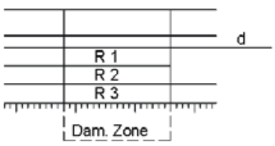
In this example, there are 3 horizontal subdivisions to be taken into account as the vertical extent of damage.

The example shows the maximum possible vertical extent of damage d + 12.5 m is positioned between H_2 and H_3. H_1 with factor v_1, H_2 with factor $v_2 > v_1$ but $v_2 < 1$ and H_3 with factor $v_3 = 1$.



The factors v_1 and v_2 are the same as above. The reserve buoyancy above H_3 should be taken undamaged in all damage cases.

Below the waterline



The combination of damages into the rooms R1, R2 and R3 positioned below the initial water line should be chosen so that the damage with the lowest s-factor is taken into account. That often results in the definition of alternative damages to be calculated and compared. If the deck taken as lower limit of damage is not watertight, down flooding should be considered.

Regulation 7-2.6.1

The parameters x_1 and x_2 are the same as parameters $x1$ and $x2$ used in regulation 7-1.

REGULATION 7-3 – PERMEABILITY

Regulation 7-3.2

1 The following additional cargo permeabilities may be used:

Spaces	Permeability at draught d_s	Permeability at draught d_p	Permeability at draught d_l
Timber cargo in holds	0.35	0.7	0.95
Wood chip cargo	0.6	0.7	0.95

2 Reference is made to MSC/Circ.998 (IACS Unified Interpretation regarding timber deck cargo in the context of damage stability requirements) regarding timber deck cargo.

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Regulation 7-3.3

1 Concerning the use of other figures for permeability "if substantiated by calculations", such permeabilities should reflect the general conditions of the ship throughout its service life rather than specific loading conditions.

2 This paragraph allows for the recalculation of permeabilities. This should only be considered in cases where it is evident that there is a major discrepancy between the values shown in the regulation and the real values. It is not designed for improving the attained value of a deficient ship of regular type by the modification of chosen spaces in the ship that are known to provide significantly onerous results. All proposals should be considered on a case-by-case basis by the Administration and should be justified with adequate calculations and arguments.

REGULATION 8 – SPECIAL REQUIREMENTS CONCERNING PASSENGER SHIP STABILITY

Regulations 8.3.2 to 8.3.5

The number of persons carried, which is specified in these paragraphs, equals the total number of persons the ship is permitted to carry (and not $N = N_1 + 2\,N_2$ as defined in regulation 6).

REGULATION 8-1 – SYSTEM CAPABILITIES AFTER A FLOODING CASUALTY ON PASSENGER SHIPS

Regulation 8-1.2

1 In the context of this regulation, "compartment" has the same meaning as defined under regulation 7-1 of these Explanatory Notes (i.e. an onboard space within watertight boundaries).

2 The purpose of the paragraph is to prevent any flooding of limited extent from immobilizing the ship. This principle should be applied regardless of how the flooding might occur. Only flooding below the bulkhead deck need be considered.

REGULATION 9 – DOUBLE BOTTOMS IN PASSENGER SHIPS AND CARGO SHIPS OTHER THAN TANKERS

Regulation 9.1

1 This regulation is intended to minimize the impact of flooding from a minor grounding. Special attention should be paid to the vulnerable area at the turn of the bilge. When justifying a deviation from fitting an inner bottom an assessment of the consequences of allowing a more extensive flooding than reflected in the regulation should be provided.

2 Except as provided in regulations 9.3 and 9.4, parts of the double bottom not extended for the full width of the ship as required by regulation 9.1 should be considered an unusual arrangement for the purpose of this regulation and should be handled in accordance with regulation 9.7.

Regulation 9.2

If an inner bottom is located higher than the partial subdivision draught d_p, this should be considered an unusual arrangement and should be handled in accordance with regulation 9.7.

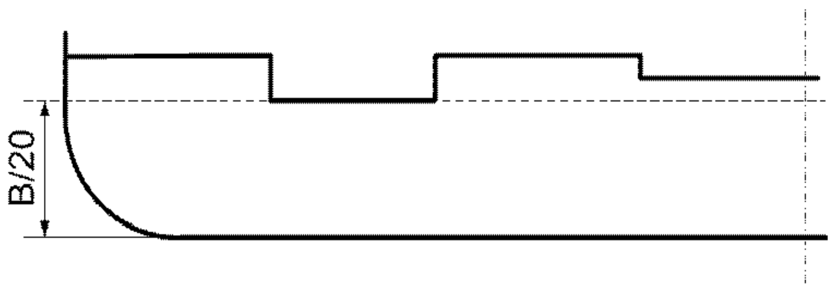
Regulation 9.6

1 Any part of a passenger ship or a cargo ship where a double bottom is omitted in accordance with regulation 9.1, 9.4 or 9.5 shall be capable of withstanding bottom damages, as specified in regulation 9.8. The intent of this provision is to specify the circumstances under which the Administration should require calculations, which damage extents to assume and what survival criteria to apply when double bottoms are not fitted.

2 The definition of "watertight" in regulation 2.17 implies that the strength of inner bottoms and other boundaries assumed to be watertight should be verified if they are to be considered effective in this context.

Regulation 9.7

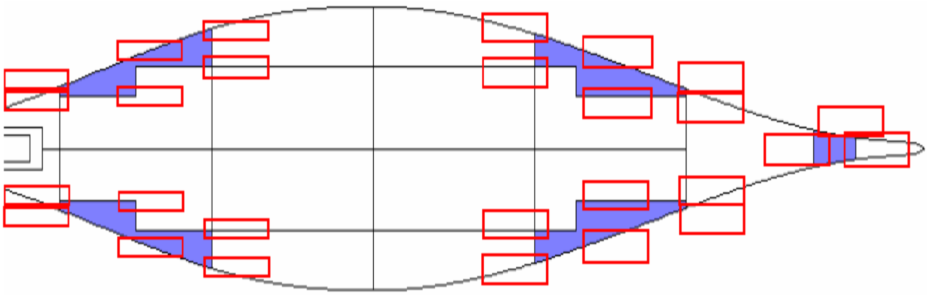
The reference to a "plane" in regulation 9.2 does not imply that the surface of the inner bottom may not be stepped in the vertical direction. Minor steps and recesses need not be considered unusual arrangements for the purpose of this paragraph as long as no part of the inner bottom is located below the reference plane. Discontinuities in way of wing tanks are covered by regulation 9.4.



Regulation 9.8

1 The term "all service conditions" used in this paragraph means the three loading conditions used to calculate the attained subdivision index A.

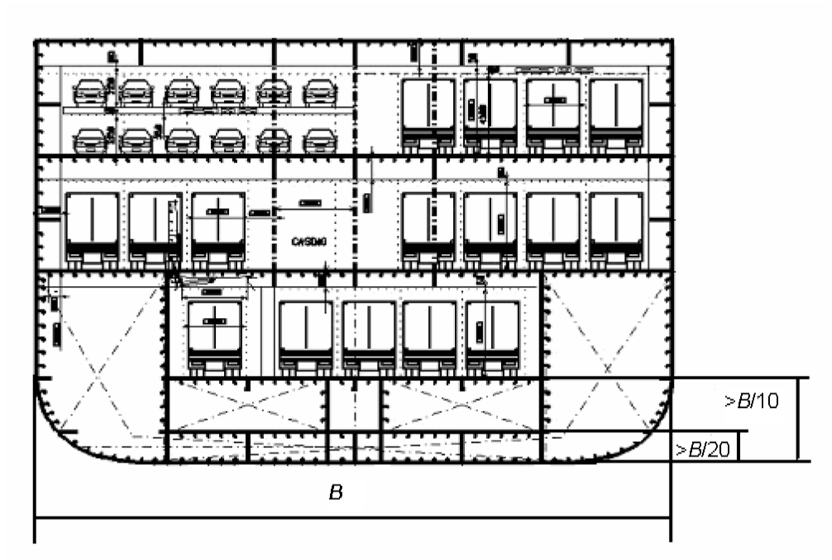
2 The damage extents specified in this paragraph should be applied to all parts of the ship where no double bottom is fitted, as permitted by regulations 9.1, 9.4 or 9.5, and include any adjacent spaces located within the extent of damage. Small wells in accordance with regulation 9.3 do not need to be considered damaged even if within the extent of the damage. Possible positions of the damages are shown in an example below (parts of the ship not fitted with a double bottom are shaded; the damages to be assumed are indicated by boxes).



Regulation 9.9

1 For the purpose of identifying "large lower holds", horizontal surfaces having a continuous deck area greater than approximately 30% in comparison with the waterplane area at subdivision draught should be taken to be located anywhere in the affected area of the ship. For the alternative bottom damage calculation, a vertical extent of *B*/10 or 3 m, whichever is less, should be assumed.

2 The increased minimum double bottom height of not more than *B*/10 or 3 m, whichever is less, for passenger ships with large lower holds, is applicable to holds in direct contact with the double bottom. Typical arrangements of ro-ro passenger ships may include a large lower hold with additional tanks between the double bottom and the lower hold, as shown in the figure below. In such cases, the vertical position of the double bottom required to be *B*/10 or 3 m, whichever is less, should be applied to the lower hold deck, maintaining the required double bottom height of *B*/20 or 2 m, whichever is less (but not less than 760 mm). The figure below shows a typical arrangement of a modern ro-ro passenger ferry.



REGULATION 10 – CONSTRUCTION OF WATERTIGHT BULKHEADS

Regulation 10.1

For the treatment of steps in the bulkhead deck of passenger ships see Explanatory Notes for regulation 13. For the treatment of steps in the freeboard deck of cargo ships see Explanatory Notes for regulation 13-1.

REGULATION 12 – PEAK AND MACHINERY SPACE BULKHEADS, SHAFT TUNNELS, ETC.

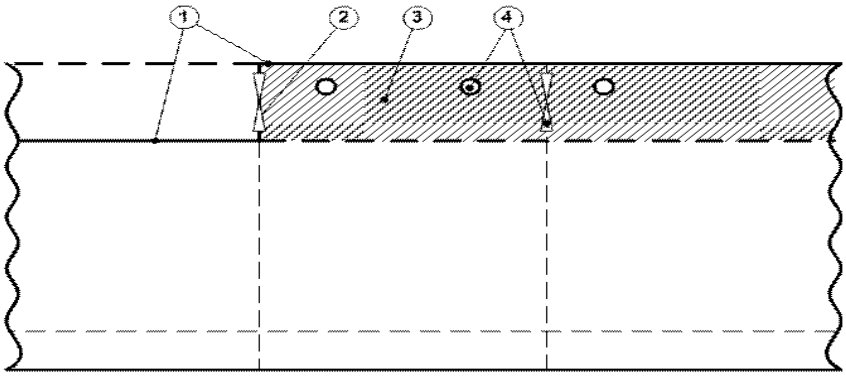
Reference is made to MSC.1/Circ.1211 (Unified interpretations to SOLAS regulation II-1/10 and regulation 12 of the revised SOLAS chapter II-1 regarding bow doors and the extension of the collision bulkhead) concerning interpretations regarding bow doors and the extension of the collision bulkhead.

REGULATION 13 – OPENINGS IN WATERTIGHT BULKHEADS BELOW THE BULKHEAD DECK IN PASSENGER SHIPS

General – Steps in the bulkhead deck

1 If the transverse watertight bulkheads in a region of the ship are carried to a higher deck which forms a vertical step in the bulkhead deck, openings located in the bulkhead at the step may be considered as being located above the bulkhead deck. Such openings should then comply with regulation 17 and should be taken into account when applying regulation 7-2.

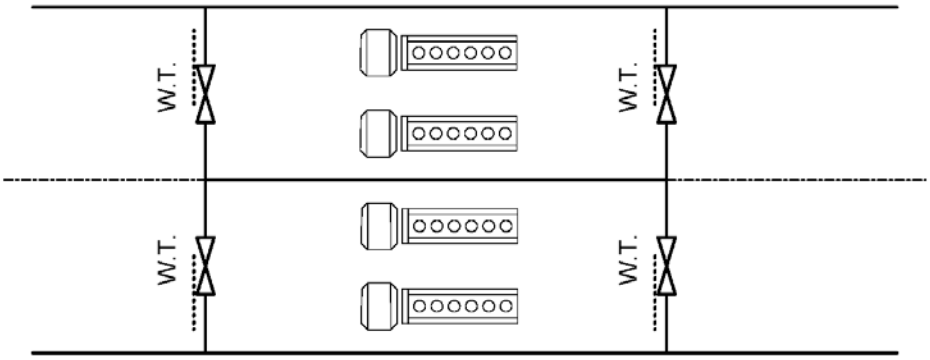
2 All openings in the shell plating below the upper deck throughout that region of the ship should be treated as being below the bulkhead deck and the provisions of regulation 15 should be applied. See figure below.



1 Bulkhead deck 2 Considered as located above the bulkhead deck
3 Ship's side 4 Considered as located below the bulkhead deck

Regulation 13.4

In cases where main and auxiliary propulsion machinery spaces, including boilers serving the needs for propulsion, are divided by watertight longitudinal bulkheads in order to comply with redundancy requirements (e.g., according to regulation 8-1.2), one watertight door in each watertight bulkhead may be permitted, as shown in the figure below.



Regulation 13.7.6

The IEC standard referenced in the footnote (IEC publication 529, 1976) has been replaced by the newer standard IEC 60529:2003.

REGULATION 13-1– OPENINGS IN WATERTIGHT BULKHEADS AND INTERNAL DECKS IN CARGO SHIPS

Regulation 13-1.1

1 If the transverse watertight bulkheads in a region of the ship are carried to a higher deck than in the remainder of the ship, openings located in the bulkhead at the step may be considered as being located above the freeboard deck.

2 All openings in the shell plating below the upper deck throughout that region of the ship should be treated as being below the freeboard deck, similar to the bulkhead deck for passenger ships (see relevant figure under regulation 13 above), and the provisions of regulation 15 should be applied.

REGULATION 15 – OPENINGS IN THE SHELL PLATING BELOW THE BULKHEAD DECK OF PASSENGER SHIPS AND THE FREEBOARD DECK OF CARGO SHIPS

General – Steps in the bulkhead deck and freeboard deck

For the treatment of steps in the bulkhead deck of passenger ships see Explanatory Notes for regulation 13. For the treatment of steps in the freeboard deck of cargo ships see Explanatory Notes for regulation 13-1.

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REGULATION 15-1– EXTERNAL OPENINGS IN CARGO SHIPS

Regulation 15-1.1

With regard to air-pipe closing devices, they should be considered weathertight closing devices (not watertight). This is consistent with their treatment in regulation 7-2.5.2.1. However, in the context of regulation 15-1, “external openings” are not intended to include air-pipe openings.

REGULATION 16 – CONSTRUCTION AND INITIAL TESTS OF WATERTIGHT DOORS, SIDESCUTTLES, ETC.

Regulation 16.2

1 Watertight doors should be tested by water pressure to a head of water measured from the lower edge of the door opening to the bulkhead deck or the freeboard deck, or to the most unfavourable final or intermediate waterplane during flooding, whichever is greater.

2 Large doors, hatches or ramps on passenger and cargo ships, of a design and size that would make pressure testing impracticable, may be exempted from regulation 16.2, provided it is demonstrated by calculations that the doors, hatches or ramps maintain watertightness at design pressure with a proper margin of resistance. Where such doors utilize gasket seals, a prototype pressure test to confirm that the compression of the gasket material is capable of accommodating any deflection, revealed by the structural analysis, should be carried out. After installation every such door, hatch or ramp should be tested by means of a hose test or equivalent.

Note: See Explanatory Notes for regulation 13 for additional information regarding the treatment of steps in the bulkhead deck of passenger ships. See Explanatory Notes for regulation 13-1 for additional information regarding the treatment of steps in the freeboard deck of cargo ships.

REGULATION 17 – INTERNAL WATERTIGHT INTEGRITY OF PASSENGER SHIPS ABOVE THE BULKHEAD DECK

General – Steps in the bulkhead deck

For the treatment of steps in the bulkhead deck of passenger ships see Explanatory Notes for regulation 13.

Regulation 17.1

Watertight sliding doors with reduced pressure head complying with the requirements of MSC/Circ.541, as may be amended, should be in line with regulation 7-2.5.2.1. These types of tested watertight sliding doors with reduced pressure head could be immersed during intermediate stages of flooding.

Regulation 17.3

These provisions regarding the open end of air pipes should be applied only to damages of longitudinal and transverse extent as defined in regulation 8.3 but limited to the bulkhead deck and involving tanks having their open end terminating within the superstructure.

APPENDIX

GUIDELINES FOR THE PREPARATION OF SUBDIVISION AND DAMAGE STABILITY CALCULATIONS

1 GENERAL

1.1 Purpose of the Guidelines

1.1.1 These Guidelines serve the purpose of simplifying the process of the damage stability analysis, as experience has shown that a systematic and complete presentation of the particulars results in considerable saving of time during the approval process.

1.1.2 A damage stability analysis serves the purpose to provide proof of the damage stability standard required for the respective ship type. At present, two different calculation methods, the deterministic concept and the probabilistic concept are applied.

1.2 Scope of analysis and documentation on board

1.2.1 The scope of subdivision and damage stability analysis is determined by the required damage stability standard and aims at providing the ship's master with clear intact stability requirements. In general, this is achieved by determining *KG*-respective *GM*-limit curves, containing the admissible stability values for the draught range to be covered.

1.2.2 Within the scope of the analysis thus defined, all potential or necessary damage conditions will be determined, taking into account the damage stability criteria, in order to obtain the required damage stability standard. Depending on the type and size of ship, this may involve a considerable amount of analyses.

1.2.3 Referring to SOLAS chapter II-1, regulation 19, the necessity to provide the crew with the relevant information regarding the subdivision of the ship is expressed, therefore plans should be provided and permanently exhibited for the guidance of the officer in charge. These plans should clearly show for each deck and hold the boundaries of the watertight compartments, the openings therein with means of closure and position of any controls thereof, and the arrangements for the correction of any list due to flooding. In addition, Damage Control Booklets containing the aforementioned information should be available.

2 DOCUMENTS FOR SUBMISSION

2.1 Presentation of documents

The documentation should begin with the following details: principal dimensions, ship type, designation of intact conditions, designation of damage conditions and pertinent damaged compartments, *KG*-respective *GM*-limit curve.

2.2 General documents

For the checking of the input data, the following should be submitted:

- .1 main dimensions;
- .2 lines plan, plotted or numerically;

.3 hydrostatic data and cross curves of stability (including drawing of the buoyant hull);

.4 definition of sub-compartments with moulded volumes, centres of gravity and permeability;

.5 layout plan (watertight integrity plan) for the sub-compartments with all internal and external opening points including their connected sub-compartments, and particulars used in measuring the spaces, such as general arrangement plan and tank plan. The subdivision limits, longitudinal, transverse and vertical, should be included;

.6 light service condition;

.7 load line draught;

.8 coordinates of opening points with their level of tightness (e.g., weathertight, unprotected);

.9 watertight door location with pressure calculation;

.10 side contour and wind profile;

.11 cross and down flooding devices and the calculations thereof according to resolution MSC.245(83) with information about diameter, valves, pipe lengths and coordinates of inlet/outlet;

.12 pipes in damaged area when the destruction of these pipes results in progressive flooding; and

.13 damage extensions and definition of damage cases.

2.3 Special documents

The following documentation of results should be submitted.

2.3.1 Documentation

2.3.1.1 Initial data:

.1 subdivision length L_s;

.2 initial draughts and the corresponding *GM*-values;

.3 required subdivision index *R*; and

.4 attained subdivision index *A* with a summary table for all contributions for all damaged zones.

2.3.1.2 Results for each damage case which contributes to the index *A*:

.1 draught, trim, heel, *GM* in damaged condition;

.2 dimension of the damage with probabilistic values *p*, *v* and *r*;

.3 righting lever curve (including GZ_{max} and range) with factor of survivability *s*;

.4 critical weathertight and unprotected openings with their angle of immersion; and

.5 details of sub-compartments with amount of in-flooded water/lost buoyancy with their centres of gravity.

2.3.1.3 In addition to the requirements in paragraph 2.3.1.2, particulars of non-contributing damages ($s_i = 0$ and $p_i > 0.00$) should also be submitted for passenger ships and ro-ro ships fitted with long lower holds including full details of the calculated factors.

2.3.2 Special consideration

For intermediate conditions, as stages before cross-flooding or before progressive flooding, an appropriate scope of the documentation covering the aforementioned items is needed in addition.

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